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TECHNICAL REPORT

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A TELEVISION BOMBSCORING SYSTEM FOR MEASURING MISS-DISTANCE ON AIR WEAPONS RANGES

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S U M M A R Y

The Defence Research Centre Salisbury has developed, in close collaboration with the RAAF, a Television Bombscoring System for measuring bombing accuracy on air weapons ranges. A detailed description of the system is given together with accuracy as determined from evaluation on a simulated bombing range.

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1. INTRODUCTION

The Defence Research Centre Salisbury was tasked to investigate improved methods of scoring weapon accuracy on air weapons ranges used by the RAAF. Two systems were proposed, a laser rangefinder system and a television system where the optical sights were replaced by TV cameras. A comparative study was conducted between the conventional optical sighting system, the laser rangefinding system and the television system(ref.1). The laser rangefinder was used to measure the distance of a bomb impact from a master quadrant hut. Impact range, and its angular displacement relative to the target were sufficient to calculate miss-distance and miss-angle. Large errors in range were observed caused by dust being scattered by the impact and wind carrying smoke and debris away from the impact point.

The TV system proved to be the most encouraging method of improving scoring accuracy and, as a result, a prototype TV bombscoring system was developed. Development was in two phases, the first being to develop the system with a hand-held programmable calculator (HP65) to compute miss-distance. Phase II (subsequent to proving the feasibility of the overall system in Phase I) incorporates a dedicated calculator into the system and introduces modifications found necessary from Phase I.

The Mark I prototype system was installed at the Evans Head air weapons range and operated successfully by RAAF personnel for approximately six months. The system was recalled and reconstructed to include a dedicated calculator. Also, it was difficult for one operator to operate the system and achieve high accuracy scoring and, as a result, a secondary console was added which incorporated a TV display in parallel with the main console display. Keyboard controls were also divided between the two operators. The Mark II system was installed at the Learmonth air weapons range during exercise "Golden West" (Plates 11 to 15) and at Lake Hart during exercise "Shifting Sands" (Plates 16 to 18).

Work is continuing in developing an engineered prototype for introducing the system into service at air weapons ranges throughout Australia. A report on this development will be prepared in due course.

2. THE CONVENTIONAL AIR WEAPONS RANGE SCORING SYSTEM

Conventional air weapons range scoring systems use two optical sights situated on two vertices of an accurately surveyed triangle with the target located at the third vertex (figure 1). Both optical sights are aligned on the bomb impact point and the angle between the baseline joining the two optical sights and the line to the impact point is read from each sight. These two readings are plotted on a plotting board and miss-distance and angle relative to a reference (e.g. true north) are estimated. This system is capable of high accuracy, however the problems and limitations in using these sights are well documented.

3. THE TV BOMBSCORING SYSTEM

The TV bombscoring system operates on a principle similar to the conventional optical scoring system with the optical sights replaced by TV cameras (figure 2). Each TV camera is centrally aligned on the target and a lens of appropriate focal length fitted such that the TV display covers a chosen radius surrounding the target. The video signal from the remote TV camera is relayed back to the main console via microwave link (or coaxial cable). Synchronizing signals are separated from the incoming video signal and used to synchronize the local TV camera. Slaving of the two cameras allows use of a video effects generator to produce a split screen display for simultaneous display on one TV monitor of the scene from the remote TV camera on the upper half of the display and the scene from the local TV camera on the lower half of the display (figure 3). This enables a video tape record to be kept for subsequent analysis and verification of scores. Two rows of alpha-numeric characters are inserted at the changeover point between the upper and lower scenes to identify the video tape record (see Table 1).

The scoring system incorporates two consoles, a main console and a secondary console, both of which are coupled to a programmable calculator for calculation of miss-distance (Plate 1). Each console is fitted also with a TV monitor. The monitors are coupled in parallel, providing an identical display to each console operator. Impacts are scored by positioning a small electronically generated cursor over the image of the bomb impact. Although two operators are required for high accuracy daylight scoring, the system may be controlled by one operator for lower accuracy daylight scoring, for scoring at night and scoring from video tape replay.

Provision has been made for accepting video signals from two different remote TV cameras (relaying the video signals back to the main console across two microwave links operating on different carrier frequencies) and synchronizing two separate local TV cameras (figure 4). This is particularly useful on ranges with two separate targets e.g. Learmonth with separate practice and H.E. targets. Video signals from the appropriate TV cameras are selected by the target selection switch on the aircraft data module.

The system can also be used in a tactical range configuration (figure 5) with the scoring consoles located up to 7 km from the local TV camera. The video signal from the remote TV camera is relayed back to a video multiplexer-synchronizer unit (Plate 10) which synchronizes the local TV camera to the remote TV camera and generates the split screen display in the field. A second microwave link is required to relay the split screen display back to the main console. Circuitry generating the split screen display within the main console is inhibited and the alpha-numeric characters and cursors are added as for the conventional configuration.

The system may operate with two tactical ranges or two conventional ranges or a combination of one tactical range and one conventional range. Again, selection is made by the target selection switch located on the aircraft data module.

3.1 The main console

The main console contains most of the electronics for the system integrated around a 17 inch ITC-Ikegami television monitor. Controls adjacent to the TV monitor (Plate 2) are described in Sections 3.1.1 to 3.1.6 and keyboard controls (Plate 3) are described in Sections 3.1.7 to 3.1.12.

3.1.1 Cursor readout (upper and lower)

Two four-digit, light emitting diode, cursor readout displays are provided as a back-up in the event of calculator failure. Each readout is proportional to the tangent of the angle subtended by the target and the bomb impact. A plotting chart similar to the present plotting chart (but marked with tangents of angles) is then used for plotting miss-distance.

3.1.2 Computer mode switches

Five switches instruct the dedicated calculator to compute miss-distance in;

(i) Polar co-ordinates (metres and degrees)

(ii) Cartesian (X-Y) co-ordinates (metres and metres) relative to,

(i) Magnetic north, or

(ii) True north, or

(iii) Aircraft heading.

A sixth switch is provided for calculation of the angular component of miss-distance as an o'clock value (hours and half hours) relative to aircraft heading.

Angular references for magnetic and true north are programmed into the calculator, while aircraft heading is read from the selected aircraft data module (see Section 3.1.7).

Calculation relative to aircraft heading is correct only where the aircraft heading is known and set into the appropriate aircraft data module prior to weapon release. A configuration of four identical aircraft data modules allows for computation of results relative to four aircraft operating on different attack headings.

The last 16 characters in the second row of the alpha-numeric string have been reserved for displaying calculated miss-distances. Radial and angular values are appended with an M and a degree symbol respectively and cartesian co-ordinate values are appended with M and M. The abbreviations MNTH, TNTH and A/HD for magnetic north, true north and aircraft heading prefix the results. Results are computed and displayed within 4 s after a combination of two scoring buttons has been selected.

3.1.3 O'clock display

A separate four digit, light emitting diode, o'clock display has been included. The o'clock value is calculated in hours and half hours relative to the aircraft heading set on the selected aircraft data module. Miss-distance and angle are still displayed within the alpha-numeric string in either polar or cartesian coordinates relative to true north, magnetic north or aircraft heading.

3.1.4 Day of year thumbwheel switches

Day of year is inserted into the alpha-numeric character string by three thumbwheel switches. Decade and year are set by small switches located on an internal printed circuit board.

3.1.5 Graticule controls

Two electronically generated graticules are superimposed on the video monitor, one for the upper display, and one for the lower display (figure 3). Each graticule appears as three short, equi-spaced vertical lines which can be expanded in overall separation (calibration) and moved horizontally (shift) by means of potentiometers located on the main console. Separate controls are located under the main console keyboard for adjusting vertical position and graticule amplitude. The purpose of these graticules is to calibrate the field of view of each TV camera (see Section 3.8).

Two independent sets of graticule adjustment potentiometers are switched by relays which are controlled by the target selection switch on the aircraft data module. This facility is used on air weapons ranges where two targets are in operation, for example, visual and radar targets at Evans Head or practice and H.E. targets at Learmonth (see Section 3.1.7).

3.1.6 Digital clock controls

Five function buttons are provided to set the digital clock readout within the alpha-numeric character string. RESET clear the display to zero. HOLD holds the count and START initiates counting. SET HOURS and SET MINUTES are used to advance the hours and the minutes by one digit each time the button is pressed.

3.1.7 Aircraft data modules (A.D.M.)

The main console is fitted with four identical plug-in aircraft data modules (Plate 5). One module is assigned to each aircraft operating on the range, hence the system caters for a maximum of four aircraft at any one time. Information such as aircrew identification, aircraft type and tail number, bomb type and pass and aircraft dive angle, bomb release height, aircraft heading and speed together with bombing mode and target selection are preset into each A.D.M. prior to weapon release. The appropriate A.D.M. is selected by a four position 'AIRCRAFT SELECT' switch which enters the information into the alpha-numeric character string on the TV display. A light on each A.D.M. indicates which module has been selected. Bombing mode and target characters may be modified by changing two electrically programmable integrated circuit packages located on an internal printed circuit board.

At air weapons ranges where there are two separate targets covered by four TV cameras (figure 4) the video is automatically selected from the appropriate TV cameras by the target selection switch. The respective calibration graticules are superimposed on the display and the calculator jumps to the program associated with the target selected. Hence, the four aircraft may attack two different targets with scores being calculated with respect to the appropriate target. Also, the programmable calculator has access to all the information contained in the alpha-numeric character display, i.e. date, time, range code and all information preset on the selected A.D.M. At present, only aircraft heading is used for the o'clock readout and for computation of miss-distance relative to aircraft heading. Each aircraft may operate on a different attack heading with the score calculated with respect to that attack heading.

3.1.8 Power switches

Three switches are located on the keyboard to switch power to the main and secondary consoles, the local TV cameras and the video tape recorder.

3.1.9 Aircraft select switch

Data on each A.D.M. are selected and entered into the alpha-numeric display by a four position aircraft select switch. The score is latched against the selected A.D.M. and the character display reverts to the default condition, i.e. the last 16 characters in the second row are blank, upon selection of any other A.D.M. The previous score may be viewed by returning to the appropriate A.D.M.

3.1.10 VTR recording light

Remote control functions for the video tape recorder are located on the secondary console. A light has been included on the main console to indicate to the main console operator that the video tape recorder has been switched to the record mode. Outputs are provided on the secondary console to indicate when the VTR is in the record or the play mode. This is useful where the Range Safety Officer is stationed at some distance from the consoles. He can ensure that the VTR is in the record mode prior to weapon release.

3.1.11 Scoring buttons

Each operator has three buttons (Table 2) from which he must make one selection for scoring an impact.

TABLE 2. SCORING BUTTONS

Button Identification	Functional Description
SCORE DET'N	Score as a detonation
SCORE UXB	Score as an unexploded bomb
NEGATIVE SIGHTING	Failure to sight bomb impact

These three buttons are electronically interlocked and the operated button may be cleared either by pressing a CLEAR button or automatically by the calculator after it has processed the cursor readout values and entered the computed result into the alpha-numeric display.

It can be seen that three scoring buttons for each of the two operators result in nine combinations of scores as shown in Table 3. Functionally, the calculator remains in a loop continually interrogating the status of the scoring buttons, jumping to an appropriate program immediately any combination of two buttons is selected.

During program execution, the calculator reads the cursor readout values (i.e. the position of the cursor in relation to the target). Simultaneously, four cross hatches (####) are entered into the alpha-numeric display. This has two important features, firstly it notifies both operators that a combination of two buttons has been selected and secondly, that the cursor controls may then be moved without affecting the computed result.

Two further buttons are located on the main console keyboard, TEST and CANCEL LAST RESULT. These are primarily intended for system expansion, for example where an external printer is added to the system. Previous records could be deleted by the CANCEL LAST RESULT and system tests could be conducted without scores being printed. The entire scoring system may be tested by superimposing the electronic cursors over the electronically generated graticules. It can be seen that there are four possible combinations (excluding the centre point) for which four standard miss-distances should be obtained.

3.1.12 Cursor control

Two electronically generated cursors are superimposed on the video signal, one for the upper display, and one for the lower display. The lower cursor can be moved from one side of the display to the other side by a CURSOR CONTROL potentiometer located on the main console keyboard. Similarly, the upper cursor is driven by a CURSOR CONTROL potentiometer located on the secondary console keyboard. Electronically generating and adding the cursor to the video signal eliminates parallax errors in aligning the cursor over the image of the bomb impact.

The electronic cursor readout is autoscaling in that the internal electronics give a readout of +1.000 when the cursor is positioned over the right hand graticule line and -1.000 when positioned over the left hand graticule line. This occurs regardless of graticule position or overall separation. Proportional readouts are obtained for other positions of the cursor up to a maximum value of ± 4.000. Forming a ratio between the cursor position and graticule separation has a number of advantages over simpler methods of measuring scan transit times. Firstly, scan amplitudes within the TV cameras may vary without degrading the system accuracy. Secondly, where calibration posts are used (see Section 3.8), a zoom lens may be fitted to each TV camera and focal length varied to cover any radius surrounding the target without the need to enter new calibration constants into the computer program. While two operators are required for high accuracy daylight scoring, the system may be controlled by one operator for lower accuracy daylight scoring, for scoring at night, and scoring from video tape replay. Consequently, the cursor control potentiometers and scoring buttons have been positioned on the keyboards where one operator may control the system when both consoles are placed side-by-side.

3.2 The secondary console

The secondary console incorporates a 17 inch TV monitor operating in parallel with the main console display. Keyboard controls are assigned as follows.

3.2.1 Cursor control and scoring buttons

The secondary console operator has a cursor control potentiometer for positioning the cursor over the image of the bomb impact in the upper display together with a set of scoring buttons which are identical to those on the main console. Operation of these buttons is described in Section 3.1.11.

3.2.2 Video tape recorder remote control unit

The video tape recorder (VTR) is controlled by a remote control unit which is located on the secondary console keyboard. This unit is interfaced with the console electronics (see Section 3.1.10).

3.2.3 VTR override switch

The video output from the VTR is displayed on both TV monitors when the VTR is operated in the PLAY mode. Operation of any other button, RECORD, REVERSE, FORWARD or STOP automatically deselects the output from the VTR, and the TV monitors revert back to the normal display. A VTR OVERRIDE switch overrides the logic connections to the remote control unit in the STOP mode, enabling stop frame analysis of the VTR record.

3.3 Microwave link

The microwave link (Microwave Associates Type MA-13CP - Plate 7) has been tested extensively at RAAF Edinburgh and at the Evans Head and Learmonth air weapons ranges to determine the effects of reflections caused by aircraft over-flying the link at low altitudes. These tests included operating the link along the centreline of the RAAF Edinburgh runway (approximately 8000 ft) with jet aircraft overflying the line-of-sight at altitudes of 50 and 100 ft. The video signal remained undisturbed even with aircraft taking off and landing within the line-of-sight.

The maximum distance over which the link was satisfactorily operated was approximately 7 km.

3.4 TV cameras

Commercially available high resolution, high scan linearity television cameras are used (ITC-Ikegami Type CTC 6000 - Plate 8). High scan linearity is the primary requirement in determining overall system accuracy. The remote TV camera is fitted with a crystal controlled synchronization pulse generator which becomes the master synchronization pulse generator for the total system. Each camera is enclosed in a sprayproof case with a sunshade (Plate 9) and mounted on an alignment head.

The video signal from the remote TV camera is relayed to the main console via a microwave link (or coaxial cable). Synchronization signals are separated from the received video signal and used to slave both the console and the local TV camera to the remote camera.

These cameras as purchased employ conventional one inch vidicon camera tubes which can be replaced by specially engraved vidicons for tactical range use (see Section 3.8 on methods of system calibration).

3.4.1 Operation by day

All TV cameras fitted with conventional type antimony trisulphide target vidicon camera tubes incorporate automatic target bias. In effect the internal voltage applied to the target electrode is controlled by an electronic feedback loop maintaining a constant average video signal amplitude over widely varying ambient light conditions. This has the advantage that lens aperture is set small (e.g. f 16) for optimum optical focus and the average video signal output remains constant for widely varying illumination levels.

3.4.2 Operation by night

In general, automatic target bias is not effective during night operation. Instead, it is desirable to manually set the target bias voltage by means of a potentiometer at the rear of the TV camera and to fully open the lens aperture. Evaluation of the TV bombscoring system at Evans Head has shown that the TV camera is effective at night. Bomb flashes affect the vidicon photoconductive layer intensely, remaining for several minutes as black spots. This form of image retention is a valuable aid for night time scoring.

3.5 Video tape recorder

An important item of equipment is the video tape recorder (VTR). It is integrated into the system and controlled by a remote control unit which is located on the secondary console keyboard. Videotape records are kept for analysis and verification of scores. Analysis may be either at normal replay rates or by stop frame analysis of the single TV frame associated with the instant of bomb detonation.

The video signal to the VTR is taken from an intermediate point within the main console electronics, recording the split screen display together with the alpha-numeric character string. The electronically generated graticules and cursors are added to the video signal on replay. Logic levels are sensed within the remote control unit to provide remote indications as to whether the VTR is in the RECORD or PLAY mode. A RECORD indication is provided to the main console operator and separate outputs are available for the Range Safety Officer.

3.6 Programmable calculator

A number of alternatives for developing a dedicated calculator were considered. One extreme was to develop a calculator from basic hardware and the other extreme was to use a commercially available programmable calculator. The latter was chosen as the most economical approach. It also added flexibility to the system. The calculator chosen was the Hewlett Packard HP9815A which is currently in use with the RAAF. Input-output sockets (option 02) are required for connecting a special interface bus (HP98135A) which interfaces the console to the calculator. The interface bus has the capacity for addressing 15 different instruments of which the console is one. It is possible to expand the system by adding for example, X-Y plotters for plotting bomb impacts, paper tape punches to provide a paper tape record or a column printer to print results. The console has been designed such that the programmable calculator has access to all the information displayed within the alpha-numeric character string, e.g., date, time, range code and all information preset into the selected aircraft data module. This information could be printed on the printer to replace the present method of filling out E.D.P. forms. Another feature of this calculator is its ability to automatically load the program, stored on magnetic tape, into memory when power is switched on. It thus reloads and restarts the program after a power failure.

3.7 Range Safety Officer display

A Range Safety Officer display (Plate 6) has been integrated into the system to display the scores for the last twelve bomb releases. The display is automatically cleared and column headings are added when the calculator is switched on. Each score is entered row by row until a maximum of twelve scores are displayed. The scores scroll upwards as each new score is entered into the last row and the top most score is lost. The display, comprising a conventional TV monitor, is connected to the main console via coaxial cable and may be located at a considerable distance from the scoring consoles.

3.8 System calibration

Two techniques are available for system calibration.

3.8.1 Calibration posts

One technique is to use calibration posts at some distance in front of each camera, situated on accurately surveyed angles and symmetrically displaced with respect to a line joining the TV camera and the target. The angle $\pm$ 5° 42' 38", whose tangent is 0.1, is convenient for subsequent computation. The lens projects an image on the flat face of the television camera tube and displacement from the centre is proportional to the tangent of the angle subtended by the target and the impact point.

If the outer lines of the electronically generated graticule are positioned over the images of the calibration posts on the TV display, all cursor readouts are multiplied by a constant of 0.1 to arrive at the tangent of the angle subtended by the target and the impact point. A sign bit is electronically generated indicating that the cursor is to the left or to the right of the target.

Irrespective of the field of view, the system always remains calibrated if the electronic graticule is superimposed over the images of the calibration posts. This has the advantage that both TV cameras may be fitted with zoom lenses and focal lengths varied to cover a radius surrounding the target which is more suitable for the type of weapon deployed. For example, a field of view covering a radius of 75 m may be chosen with a proportional increase in scoring accuracy when compared with a radius of 290 m. In evaluation of the TV bomb-scoring system a theoretical 99% circular error probability radius of 290 m was used.

3.8.2 Engraved vidicons

The second technique is to fit each camera with a special vidicon camera tube where the graticule is etched into the internal photoconductive layer. This is advantageous where calibration posts are impractical because of the terrain or where an air weapons range must be established quickly. In operation, a clip-on viewfinder television monitor is attached to each camera in turn, and the central engraving aligned on the target. The electronically generated graticule is positioned over the image of the engraved graticule. Lens focal length now becomes a critical parameter in calibrating the system. The conversion constant to convert cursor readouts to tangents of angles is given by

$$\text{conversion constant} = D/fL$$

where

D = distance (mm) between centre and outer engraving within the camera tube;

fL = lens focal length (mm).

Fixed focal length lenses may be used, whereby the limited selection of focal lengths dictates the fields of view for the TV camera. Alternatively, a zoom lens may be used with the focal length control mechanically locked to

$$\text{focal length (mm)} = \frac{6.3}{\tan(\sin^{-1}(\frac{R}{S}))}$$

where

R = radius (m) surrounding target covered by the field of view;

S = distance (m) from the camera to the target.

The two disadvantages of this system are that the focal length must be set in an optical laboratory and, once set, it cannot be varied on the range to change the field of view.

3.9 Reliability

The Mark I prototype TV bombscoring system was operated at the Evans Head air weapons range for approximately six months without recorded failure. No diary was kept for the total operating time.

A record was kept however, for the Mark II installation at the Learmonth air weapons range during Exercise "Golden West". Total operating time over the period 30th October to 30th November, 1977 was 162 hours without failure.

3.10 System evaluation

3.10.1 The simulated bombing range

A simulated bombing range has been surveyed on the RAAF Edinburgh airfield by the Department of Administrative Services, (previously the Department of Services and Property), for evaluating the TV bombscoring system (see figure 6). Four simulated bomb impact points are located on each of the eight radial arms, designated A to H. Arm A lies on the arbitrary grid north. All distances are in metres hence, the point B170 is 170 m from the centre and at an angle of 45° with respect to the arbitrary grid north. TV camera (west) is located 1065.985 m from the target and TV camera (east) is 1030.058 m from the target with a baseline of 1453.865 m. These distances give an angle of intersection at the target of 87° 49' 06". Calibration posts W and X (TV camera - west) and Y and Z (TV camera - east) were surveyed on angles of ± 5° 21' 33" and ± 5° 32' 42" respectively.

3.10.2 Installation at RAAF Edinburgh

The TV cameras were installed at positions TV camera (west) and TV camera (east) and the scoring consoles located in a van at TV camera (east). Transmission of the video signal from the remote TV camera to the master site was via a Microwave Associates Type MA-13CP microwave link. Bomb flashes were simulated by an operator standing on the survey point and reflecting the sun's image at each TV camera by means of a small mirror.

Zoom lenses were not available and hence fixed focal length lenses were used with both TV cameras. These did not give fields of view which covered the entire 290 m radius. Calculated minimum radii were 263 m for TV camera (west) and 254 m for TV camera (east). Figure 6 shows the coverage in relation to the 290 m radius.

The system was evaluated firstly with the TV cameras fitted with engraved vidicons and thereafter using calibration posts. Results obtained are shown in Tables 4 and 5 respectively.

3.10.3 Explanation of Tables 4 and 5

The TV bombscoring system calculated a radius and an angle relative to the arbitrary grid north for each evaluated point. These results are compared with the survey data to determine a radial error and an angular error as shown in figure 7.

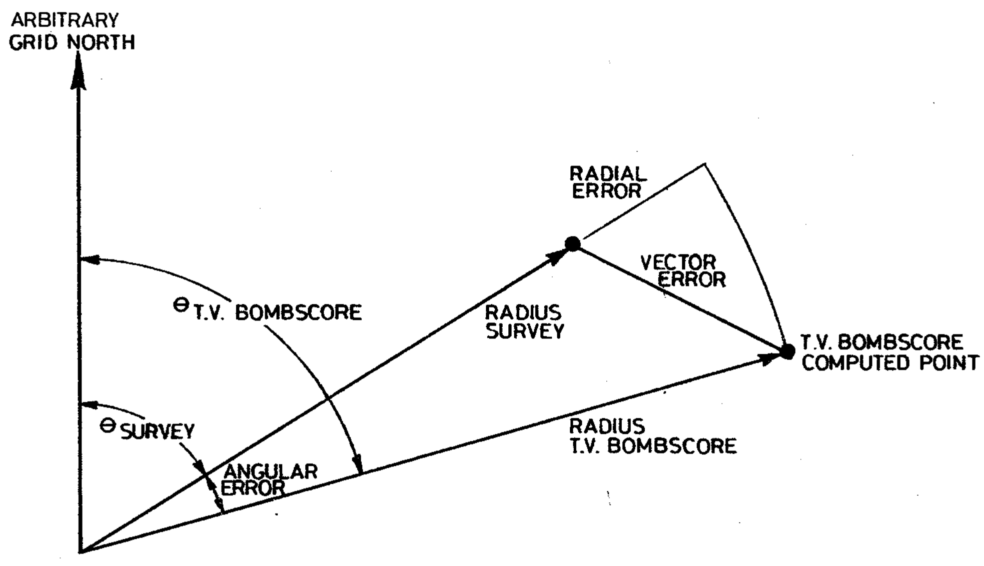

Figure 7. Error terminology

The radial and angular errors are combined to give a vector or absolute error in metres. A maximum error and an average error are computed for each of the radial error, the angular error and the vector error over the number of points evaluated. Table 4 differs from Table 5 in that another column has been introduced to show the repeatability of measurements. Most points were evaluated twice, but at different times. The difference in vector error was computed for each point where two readings were available.

4. CONCLUSIONS

The TV bombscoring system offers numerous advantages when compared with the conventional optical sighting system. There is a chain of human operations in the optical sighting system, all of which are subject to possible errors i.e. sighting the impact, reading the scale, communicating the angles back to the master quadrant hut and finally plotting the result. By comparison, the human operations in the TV scoring system are limited to those of superimposing the electronically generated cursors and graticules over the images of the bomb impact and the calibration marks respectively, but with more time available for the latter. All processes thereafter are electronic and not subject to human error.

Other advantages of the TV scoring system are as follows.

(a) The result is available within 4 s of scoring an impact.

(b) Miss-distance may be selected in polar or cartesian co-ordinates relative to true north, magnetic north or aircraft heading. A separate o'clock readout is provided for computation of o'clock readings relative to aircraft heading.

(c) Four aircraft may operate on four different attack headings with scores being calculated with respect to that attack heading.

(d) Aircraft may attack two different targets at intervals of greater than 4 s.

(e) The remote site is unmanned and may be inside the danger area. Both operators score from a single building or van which may be airconditioned and therefore more conducive to better scoring.

(f) A video tape record is available for checking scores and for closer scrutiny of events e.g. unexploded bombs. The video tape recorder also makes it possible to score individual impacts in a multiple weapon release provided each weapon is released at intervals greater than 20 milliseconds.

System accuracy is a function of TV camera field of view and, as a rule of thumb, the accuracy is approximately 1 m error per 100 m radial field of view. Calibration posts make it possible to vary field of view by means of a zoom lens without affecting system calibration.

Evaluation at RAAF Edinburgh has shown a maximum vector or absolute error for the scoring system of 2.77 m using calibration posts and 3.00 m when using camera tubes with internal graticules. The average vector errors were 1.6 m and 1.45 m respectively. These results should be compared with those obtained in reference 1 where it was stated that the experimental system was capable of scoring with an average error of less than 1 m. Actual results obtained in reference 1 were 6.44 ft maximum error and 2.5 ft average error over 17 points.

Comparing range configurations for the experimental system and the prototype evaluated at RAAF Edinburgh, the experimental results were obtained with a 26° field of view for each TV camera and located at distances of 453.07 m and 454.88 m from the target. This gives a radial cover of 102 m surrounding the target.

The prototype system used TV cameras with lenses providing 28° fields of view and located at distances of 1065.985 m and 1030.058 m from the target giving a radial cover of 263 m and 254 m respectively. System accuracy is proportional to the radius covered by each TV camera, for example, if the lenses gave a field of view covering 25 m surrounding the target, then the accuracy would be a fraction of a metre.

It can be assumed that the prototype system is capable of a 1 m maximum error at fields of view which cover up to the 100 m radius.

5. ACKNOWLEDGEMENTS

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REFERENCE

No.	Author	Title
1	Faulkner, D.W.	"Comparative Performance of a Television System, Quadrant Hut System and Laser Rangefinder in Scoring Bomb Impacts on RAAF Air Weapons Ranges". WRE-TN-1594 (AP), August 1976

TABLE 1. ALPHANUMERIC CHARACTER DISPLAY

TYPICAL DISPLAY:

```
33478LE1132:33 0817 277° 480 3306
07DIV45° 82R1100 MNTH   56M  123°
```

INTERPRETATION:

Character row 1	Example	Remarks
1 2 3	3 3 4	Day of year - set by front panel thumbwheel switches.
4 5	7 8	Decade and Year - set by small dual in-line switches located on an internal printed circuit board.
6 7	L E	Range code - set by small dual in-line switches located on an internal printed circuit board.
8 9 10 11 12 13 14	1 1 3 2 : 3 3	Time in hours minutes and seconds derived from an internal crystal controlled digital clock - set by front panel switches.
15		Blank
16 17 18 19	0 8 1 7	) Aircraft code))))) Aircraft tail number))) Set by thumbwheel switches on Aircraft Data Module (A.D.M.)
20		Blank
21 22 23 24 25 26 27	2 7 7 ° 4 8 0	))) Aircraft heading))) Set by thumbwheel switches on A.D.M.) Aircraft speed))
28		Blank
29 30 31 32	3 3 0 6	))) Pilot Code)))) Navigator Code) Set by thumbwheel switches on A.D.M.

TABLE 1. ALPHANUMERIC CHARACTER DISPLAY (CONTD.)

Character row 2	Example	Remarks
1 2	0 7	Bomb pass - set on A.D.M.
3 4 5	D I V	Bombing mode - selected from one of thirteen buttons on A.D.M.
6 7 8	4 5 °	Dive angle - set by thumbwheel switches on A.D.M.
9 10	8 2	Bomb type - set by thumbwheel switches on A.D.M.
11	R	Target - selected by two position push button switch on A.D.M.
12 13 14 15	1 1 0 0	Release height - set in tens of feet by three thumbwheel switches on A.D.M. but displayed in feet.
16		Blank
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32	M N T H 5 6 M 1 2 3 °	Normal score display area - entered into character display by the programmable calculator. The calculator has the capacity to overwrite information into all or part of the entire alpha-numeric display area.

TABLE 2. See page 5.

TABLE 3. COMBINATIONS OF SCORE BUTTONS

	Operator 1 (local camera)	Operator 2 (remote camera)	Remarks and typical display messages *
1	SCORE DET'N	SCORE DET'N	Normal score MNTH 36M 270°
2	SCORE DET'N	SCORE UXB	Normal score TNTH 36M -26M
3	SCORE DET'N	NEGATIVE SIGHTING	Local sighting only LOCAL SIGHTING ONLY
4	SCORE UXB	SCORE DET'N	Normal score AH/D 75M -24M
5	SCORE UXB	SCORE UXB	Unexploded bomb UXB MNTH 35M 270°
6	SCORE UXB	NEGATIVE SIGHTING	Unexploded bomb local sighting only UXB LOCAL SIGHTING ONLY 129.37°
7	NEGATIVE SIGHTING	SCORE DET'N	Remote sighting only REMOTE SIGHTING ONLY
8	NEGATIVE SIGHTING	SCORE UXB	Unexploded bomb remote sighting only UXB REMOTE SIGHTING ONLY 209.59°
9	NEGATIVE SIGHTING	NEGATIVE SIGHTING	Negative sighting NEG.SIGHTING,OR UXB OR NO BOMB!

* Messages shown in upper case

NOTES ON TABLE 3.

1. Normal score (1,2,4). Miss-distance is calculated and displayed in polar or cartesian co-ordinates relative to magnetic north, true north or aircraft heading. Results are displayed within 4 s after pressing both scoring buttons.

2. Local/Remote sighting only (3,7). One sighting only from either the master or remote quadrant hut. Message displayed and no results are calculated.

3. Unexploded bomb (5). Normal score is calculated but prefixed with the message UXB.

4. UXB local/remote sighting only (6,8). One sighting only on an unexploded bomb. The appropriate cursor readout is converted to an angular value which is subtracted from or added to (depending whether the cursor is to the left or to the right of the target) the magnetic north bearing of the target in relation to the respective TV camera location.

5. Negative sighting (9). If neither operator sights an impact it is either a negative sighting or an unexploded bomb whose position is unknown or a no bomb.

TABLE 4. EVALUATION OF TV BOMBSCORING SYSTEM ON A SIMULATED AIR WEAPONS RANGE AT RAAF EDINBURGH USING CAMERA TUBES WITH INTERNAL GRATICULES

Survey			TV bombscore		Error		
Point	Radius (m)	Angle (°)	Radius (m)	Angle (°)	Radius (m)	Angle (°)	Vector (m)
A35	35.0	0.0	35.29	1.1372	0.29	1.14	0.76
A85	85.0	0.0	84.86	1.0469	0.14	1.05	1.56
A150	150.0	0.0	148.90	359.7243	1.10	0.28	1.31
A270	270.0	0.0	NOT EVALUATED				
B50	50.0	45.0	49.96	45.2925	0.04	0.29	0.26
B95	95.0	45.0	94.47	44.8108	0.53	0.19	0.62
B170	170.0	45.0	167.40	45.0520	2.60	0.05	2.60
B240	240.0	45.0	239.50	45.1870	0.50	0.19	0.93
C20	20.0	90.0	21.56	90.8345	1.56	0.83	1.59
C60	60.0	90.0	60.50	89.1993	0.50	0.80	0.98
C130	130.0	90.0	128.60	89.6347	1.40	0.37	1.62
C280	280.0	90.0	NOT EVALUATED				
D30	30.0	135.0	30.68	132.5482	0.68	2.45	1.47
D70	70.0	135.0	69.56	134.0031	0.44	1.00	1.29
D180	180.0	135.0	178.49	134.4727	1.51	0.53	2.24
D260	260.0	135.0	NOT EVALUATED				
E15	15.0	180.0	14.98	178.0643	0.02	1.94	0.51
E65	65.0	180.0	NOT EVALUATED				
E140	140.0	180.0	138.68	179.6802	1.32	0.32	1.53
E230	230.0	180.0	227.74	179.9103	2.26	0.09	2.29
F45	45.0	225.0	44.70	224.6036	0.30	0.40	0.43
F90	90.0	225.0	88.98	224.7635	1.02	0.24	1.08
F190	190.0	225.0	188.35	224.9163	1.65	0.08	1.67
F265	265.0	225.0	NOT EVALUATED				
G55	55.0	270.0	NOT EVALUATED				
G100	100.0	270.0	100.41	271.3858	0.41	1.39	2.46
G155	155.0	270.0	153.13	269.8067	1.87	0.19	1.94
G265	265.0	270.0	NOT EVALUATED				
H25	25.0	315.0	24.18	317.4297	0.82	2.43	1.33
H75	75.0	315.0	NOT EVALUATED				
H120	120.0	315.0	118.50	316.2470	1.50	1.25	3.00
H220	220.0	315.0	NOT EVALUATED				
AVERAGE ERROR OVER 23 POINTS					0.98	0.76	1.45
MAXIMUM ERROR OVER 23 POINTS					2.60	2.45	3.00

TABLE 5. EVALUATION OF TV BOMBSCORING SYSTEM ON A SIMULATED AIR WEAPONS RANGE AT RAAF EDINBURGH USING CALIBRATION POSTS

Survey			TV bombscore		Error			Repeatability
Point	Radius (m)	Angle (°)	Radius (m)	Angle (°)	Radius (m)	Angle (°)	Vector (m)	Vector (m)
A35	35.0	0.0	36.11	3.2538	1.11	3.25	2.30	
A35	35.0	0.0	36.17	2.8353	1.17	2.84	2.11	0.19
A85	85.0	0.0	86.09	0.8500	1.09	0.85	1.67	
A85	85.0	0.0	85.71	0.8026	0.71	0.80	1.39	0.28
A150	150.0	0.0	151.27	0.2905	1.27	0.29	1.48	
A150	150.0	0.0	150.80	0.2862	0.80	0.29	1.10	0.38
A270	270.0	0.0	NOT EVALUATED					
B50	50.0	45.0	52.20	46.2862	2.20	1.29	2.48	
B50	50.0	45.0	51.80	45.5981	1.80	0.60	1.88	0.60
B95	95.0	45.0	96.89	45.7718	1.89	0.77	2.29	
B95	95.0	45.0	96.80	45.3274	1.80	0.33	1.88	0.41
B170	170.0	45.0	170.69	45.3992	0.69	0.40	1.37	
B170	170.0	45.0	171.28	45.3195	1.28	0.32	1.59	0.22
B240	240.0	45.0	NOT EVALUATED					
C20	20.0	90.0	22.43	88.0442	2.43	1.96	2.54	
C20	20.0	90.0	22.47	88.7217	2.47	1.28	2.51	0.02
C60	60.0	90.0	61.63	88.9049	1.63	1.10	2.00	
C60	60.0	90.0	61.30	88.5489	1.30	1.45	2.01	0.01
C130	130.0	90.0	130.76	89.1398	0.76	0.86	2.10	
C130	130.0	90.0	130.90	89.6718	0.90	0.33	1.17	0.93
C280	280.0	90.0	NOT EVALUATED					
D30	30.0	135.0	31.02	130.2374	1.02	4.76	2.73	
D30	30.0	135.0	30.76	130.3809	0.76	4.62	2.56	0.17
D70	70.0	135.0	69.86	132.7307	0.14	2.27	2.77	
D70	70.0	135.0	71.02	133.3171	1.02	1.68	2.31	0.46
D180	180.0	135.0	179.43	134.5560	0.57	0.44	1.50	
D180	180.0	135.0	NOT EVALUATED					
D260	260.0	135.0	NOT EVALUATED					
E15	15.0	180.0	15.48	173.7024	0.48	6.30	1.74	
E15	15.0	180.0	15.35	176.0012	0.35	4.00	1.12	0.63
E65	65.0	180.0	65.38	178.9716	0.38	1.03	1.23	
E65	65.0	180.0	65.36	178.9516	0.36	1.05	1.25	0.02
E140	140.0	180.0	140.92	179.6298	0.92	0.37	1.29	
E140	140.0	180.0	140.79	179.7934	0.79	0.21	0.94	0.35
E230	230.0	180.0	230.52	180.0195	0.52	0.02	0.53	
E230	230.0	180.0	230.46	177.9373	0.46	0.06	0.52	0.00
F45	45.0	225.0	44.44	224.2138	0.56	0.79	0.83	
F45	45.0	225.0	43.87	224.3214	1.13	0.68	1.25	0.42
F90	90.0	225.0	89.60	224.4927	0.40	0.51	0.89	
F90	90.0	225.0	89.71	223.9289	0.29	1.07	1.70	0.81
F190	190.0	225.0	190.45	224.7275	0.45	0.27	1.01	
F190	190.0	225.0	189.98	224.4652	0.02	0.53	1.77	0.76
F265	265.0	225.0	NOT EVALUATED					

TABLE 5. EVALUATION OF TV BOMBSCORING SYSTEM ON A SIMULATED AIR WEAPONS RANGE AT RAAF EDINBURGH USING CALIBRATION POSTS (CONT'D.)

Survey			TV bombscore		Error			Repeatability
Point	Radius (m)	Angle (°)	Radius (m)	Angle (°)	Radius (m)	Angle (°)	Vector (m)	Vector (m)
G55	55.0	270.0	53.77	270.9674	1.23	0.97	1.53	
G55	55.0	270.0	54.48	270.1298	0.52	0.13	0.53	1.00
G100	100.0	270.0	99.46	270.2982	0.54	0.30	0.75	
G100	100.0	270.0	99.69	269.8722	0.31	0.13	0.38	0.37
G155	155.0	270.0	155.35	269.9182	0.35	0.08	0.41	
G155	155.0	270.0	155.03	269.9419	0.03	0.06	0.16	0.25
G265	265.0	270.0	NOT EVALUATED					
H25	25.0	315.0	24.48	318.9800	0.52	3.98	1.80	
H25	25.0	315.0	23.59	319.8185	1.41	4.82	2.48	0.69
*H75	73.0	315.0	72.61	316.9771	0.39	1.98	2.54	
*H75	73.0	315.0	71.83	316.7670	1.17	1.77	2.52	0.02
H120	120.0	315.0	120.21	316.1810	0.21	1.18	2.48	
H120	120.0	315.0	120.02	315.2885	0.02	0.29	0.60	1.88
H220	220.0	315.0	220.80	315.3775	0.80	0.38	1.66	
H220	220.0	315.0	221.20	315.3322	1.20	0.33	1.75	0.10
AVERAGE ERROR OVER 51 POINTS					0.87	1.29	1.60	
MAXIMUM ERROR OVER 51 POINTS					2.47	6.30	2.77	
AVERAGE OVER 25 COMPARISONS								0.44
MAXIMUM OVER 25 COMPARISONS								1.88

*Obscured by runway marker, point moved 2 m towards centre.
All angles relative to arbitrary grid north.

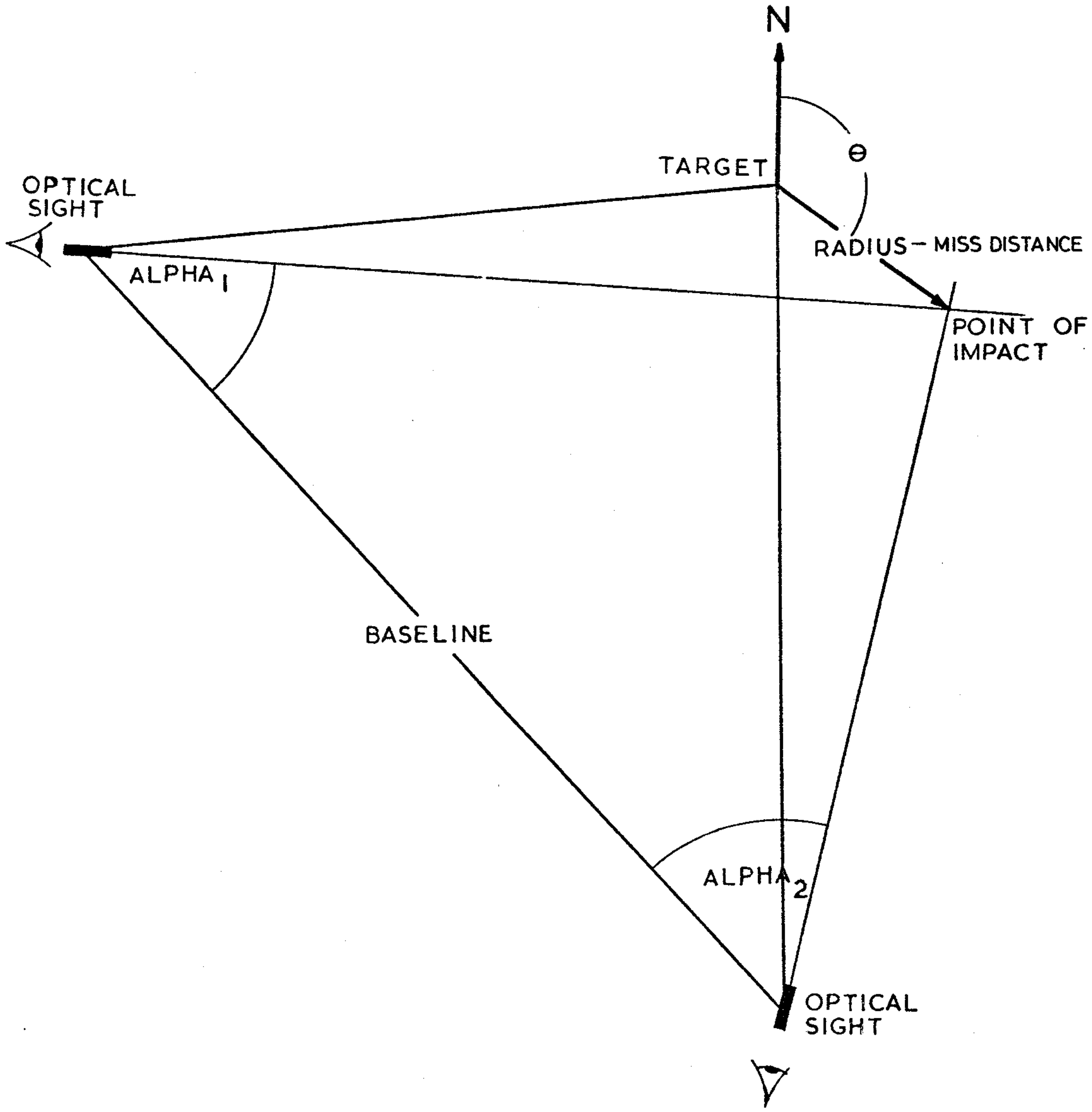


Figure 1. Conventional air weapons range scoring system

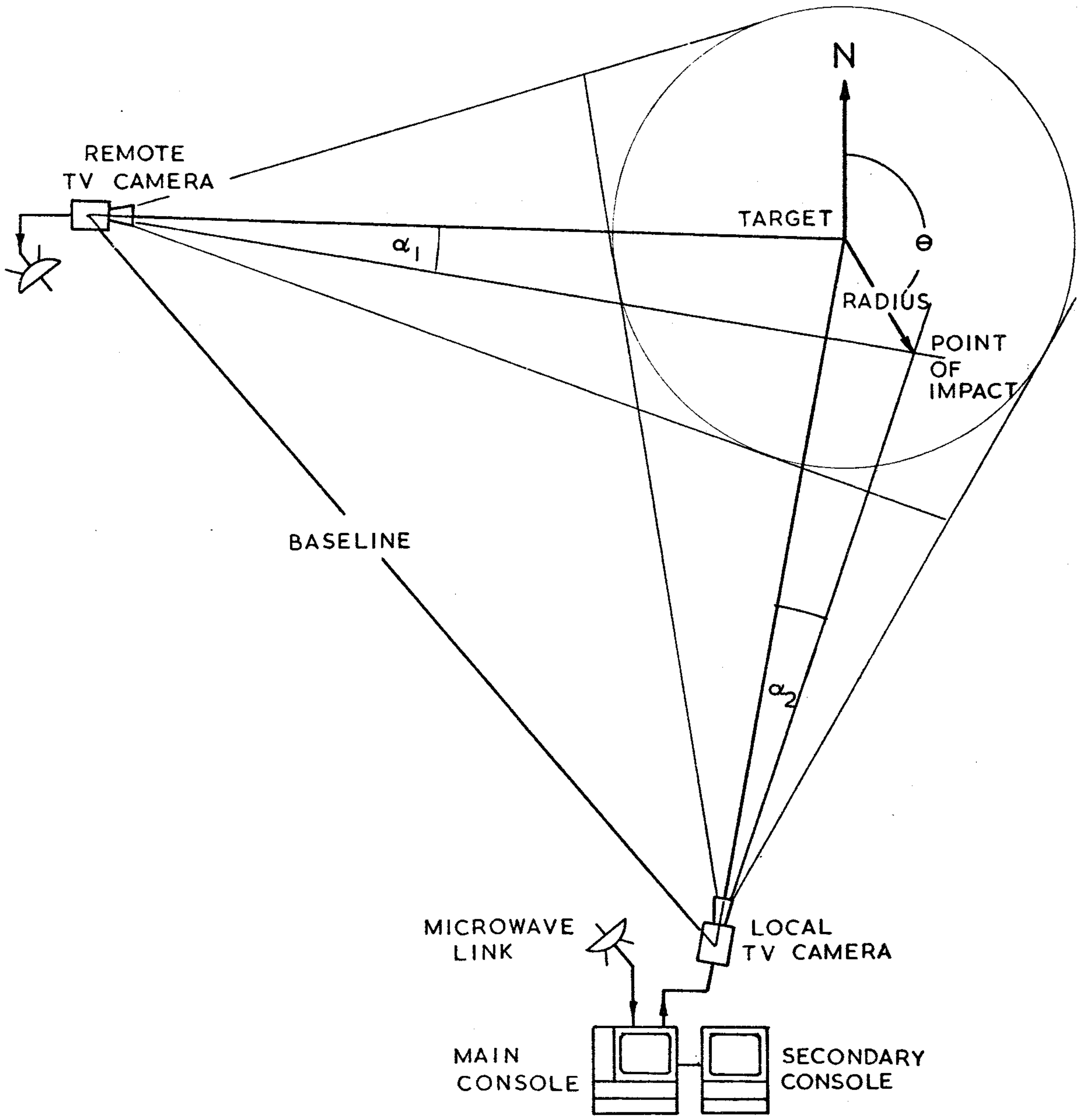


Figure 2. Television bombscoring system

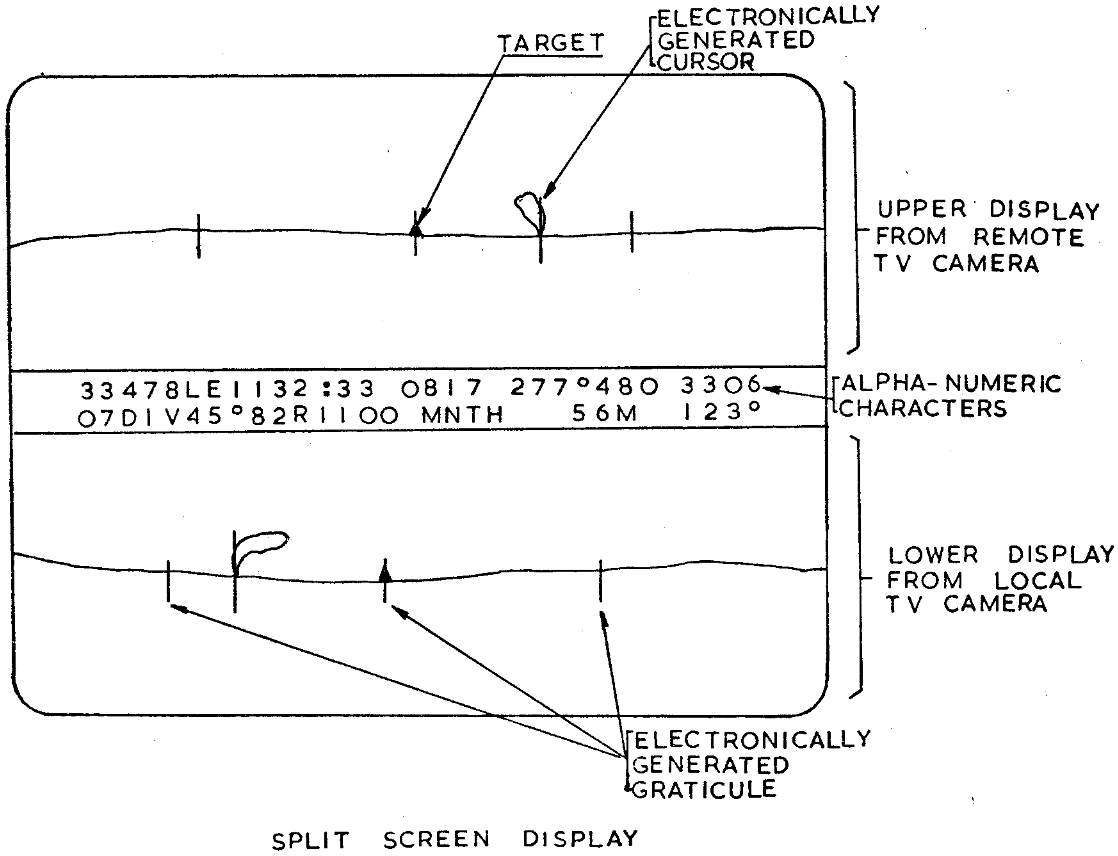


Figure 3. Television bombscoring system video display.

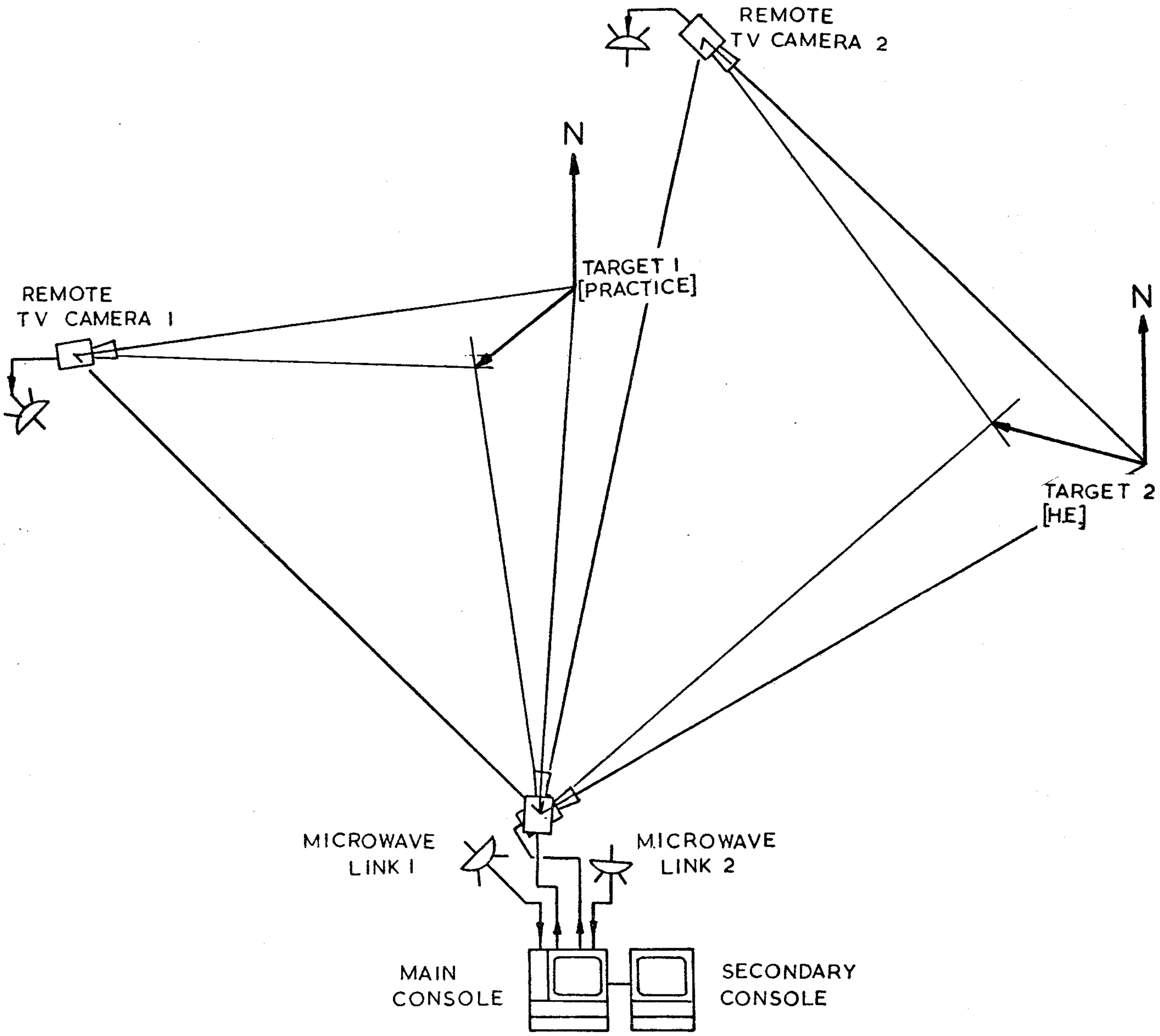


Figure 4. Television bombscoring system configuration for air weapons ranges with two targets

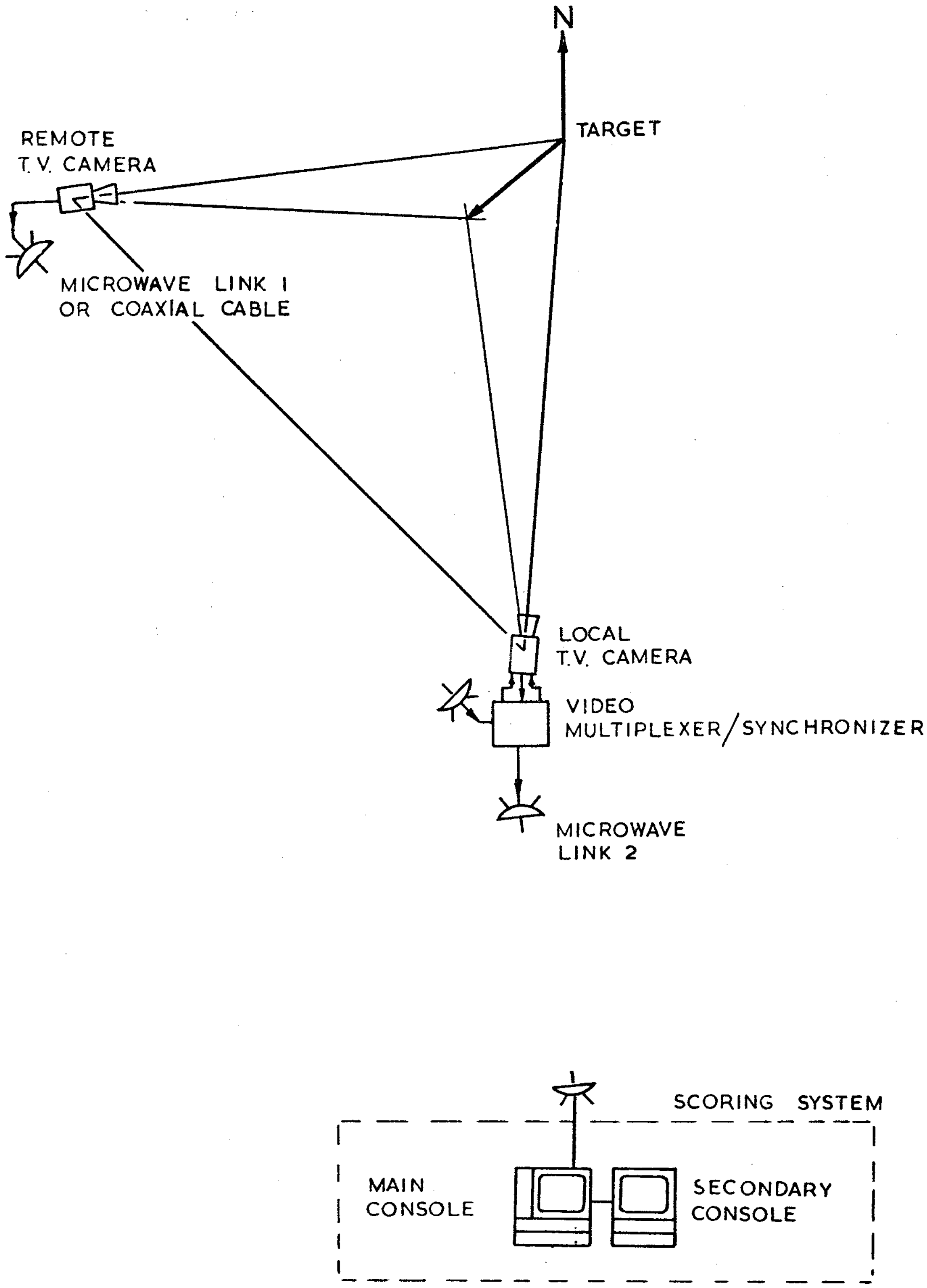


Figure 5. Television bombscoring system with remote scoring

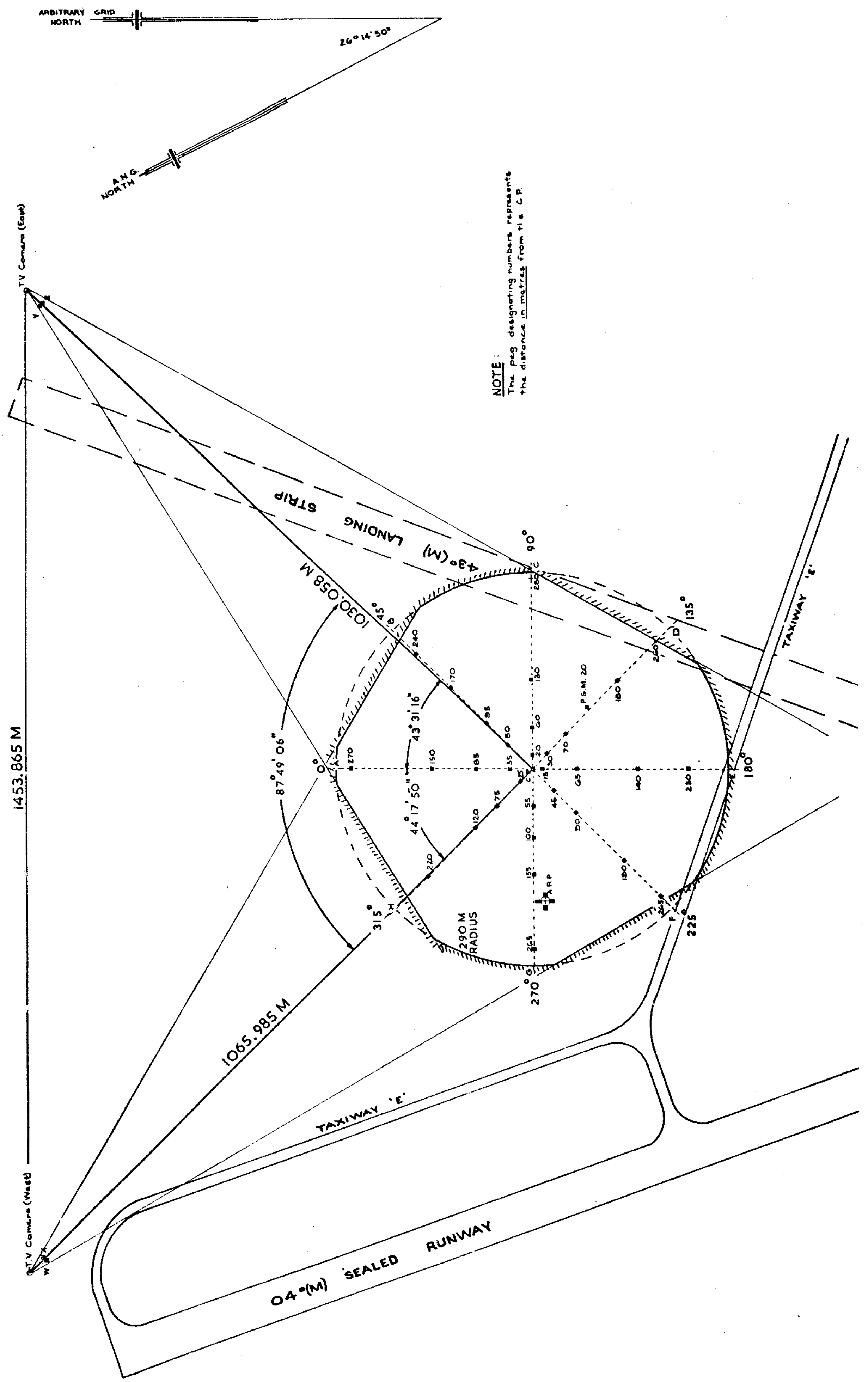


Figure 6. Edinburgh - layout of bombing triangle

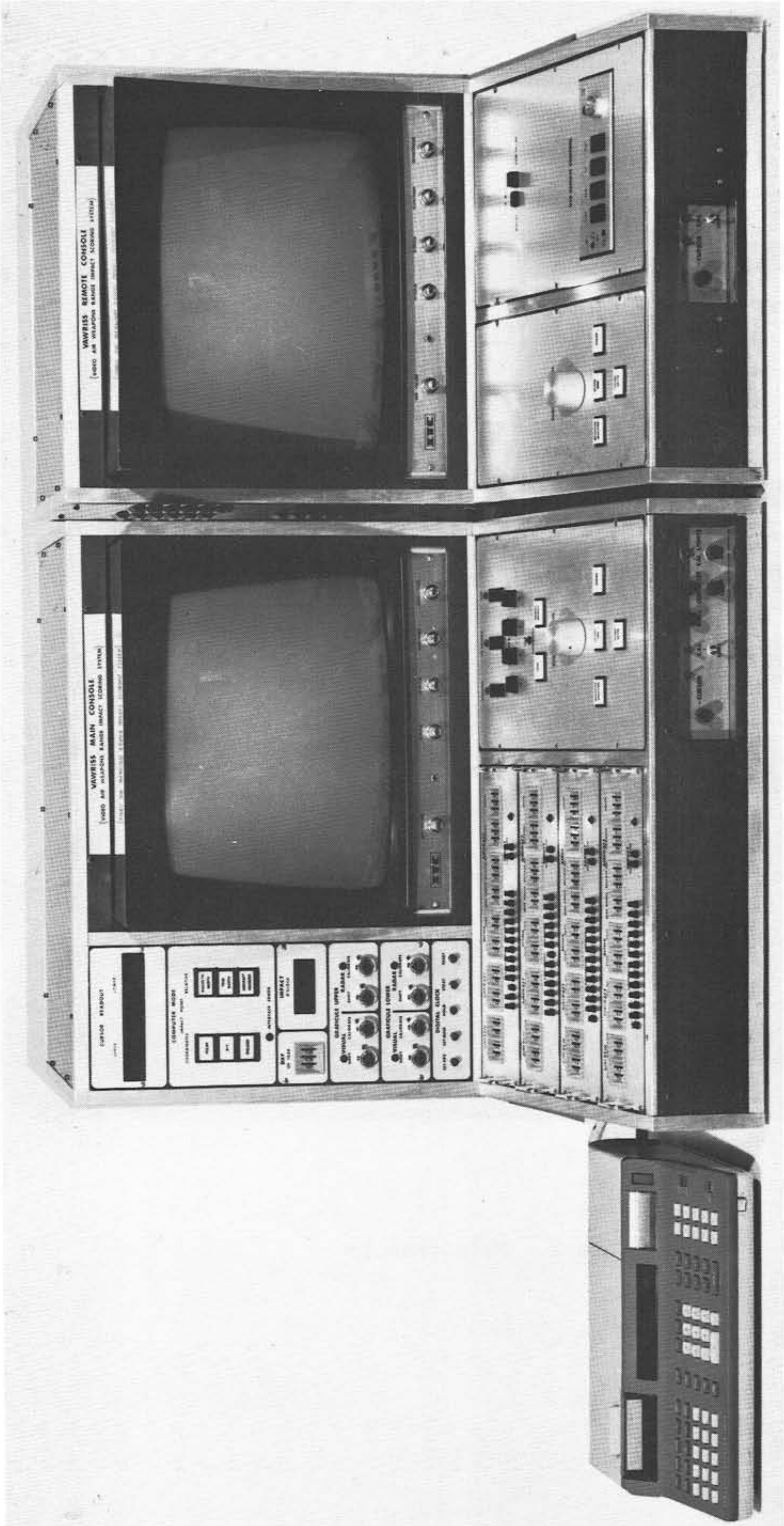


Plate 1. The TV bombscoring system

Plate 2. Main console

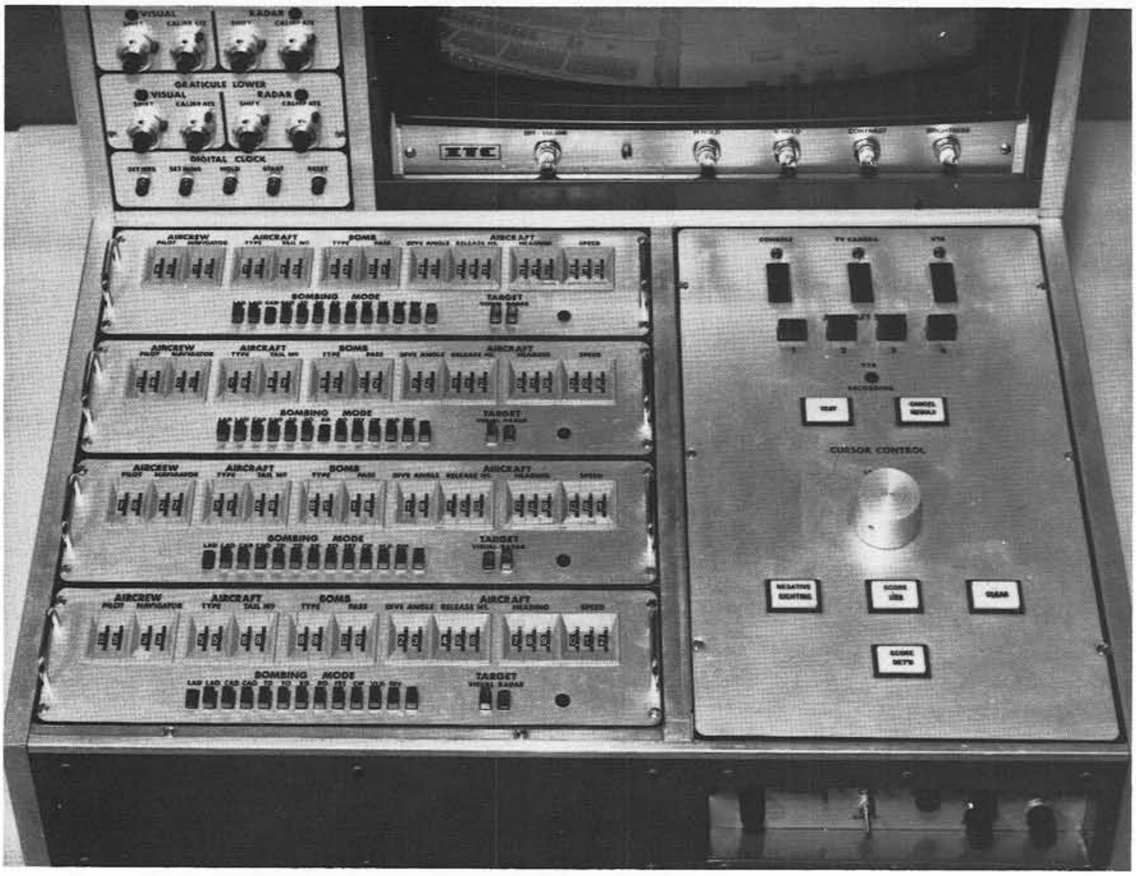


Plate 3. Main console keyboard

Plate 4. Secondary console keyboard

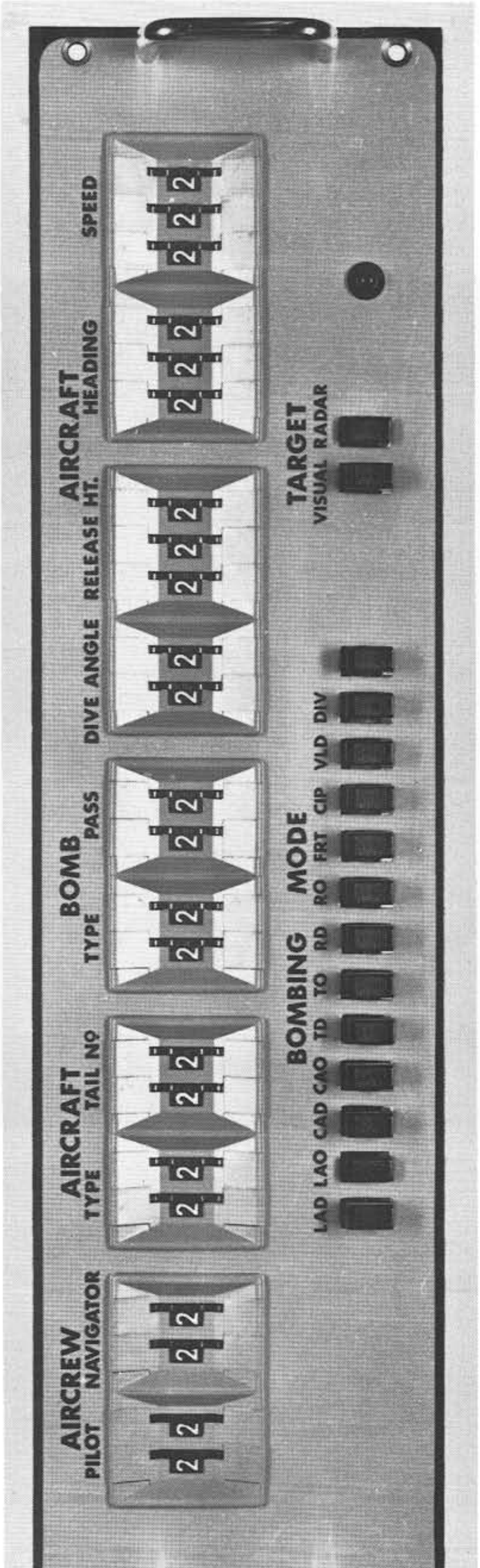
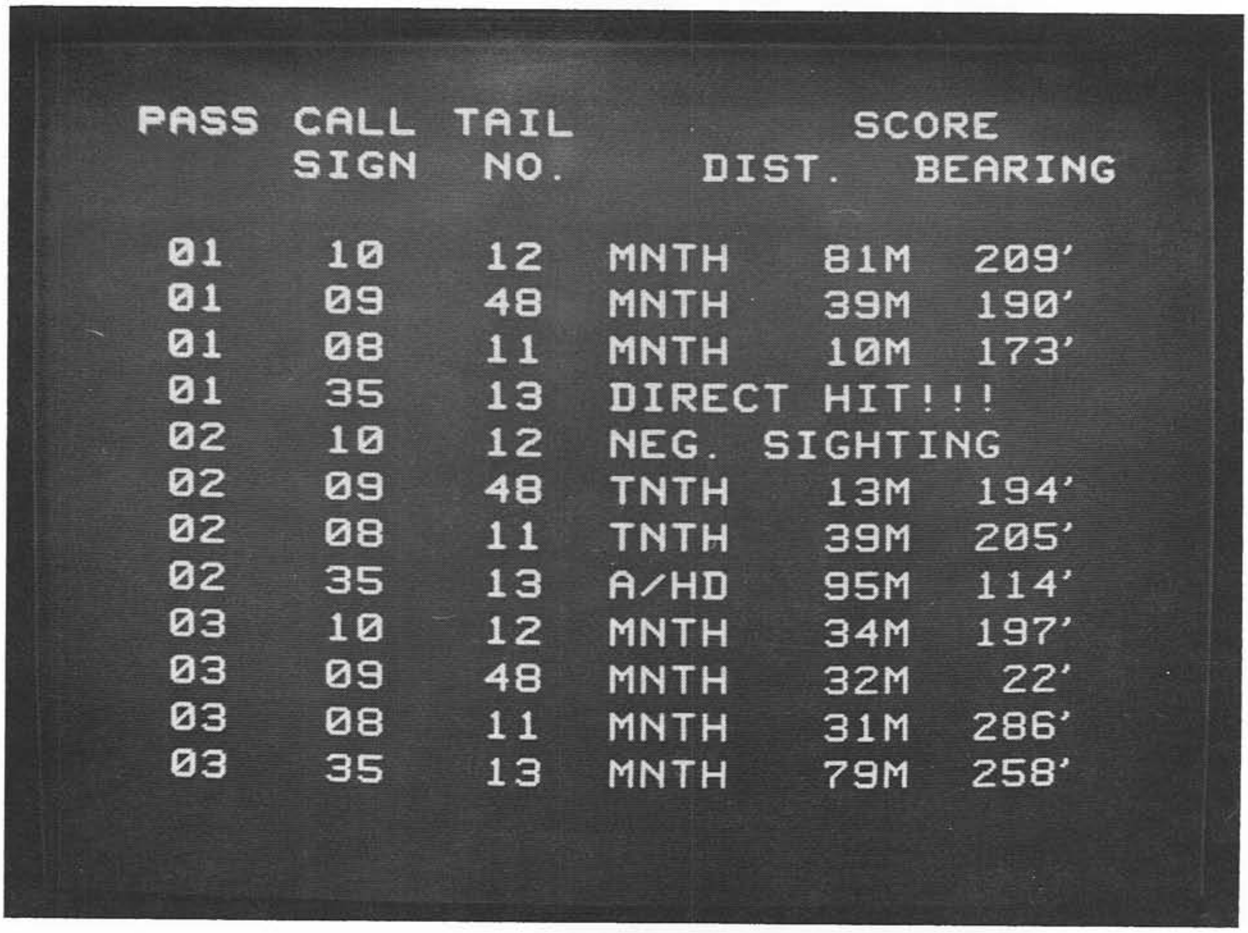


Plate 5. Aircraft data module



PASS	CALL SIGN	TAIL NO.	SCORE	DIST.	BEARING
01	10	12	MNTH	81M	209'
01	09	48	MNTH	39M	190'
01	08	11	MNTH	10M	173'
01	35	13	DIRECT HIT!!!		
02	10	12	NEG. SIGHTING		
02	09	48	TNTH	13M	194'
02	08	11	TNTH	39M	205'
02	35	13	A/HD	95M	114'
03	10	12	MNTH	34M	197'
03	09	48	MNTH	32M	22'
03	08	11	MNTH	31M	286'
03	35	13	MNTH	79M	258'

Plate 6. Range Safety Officer score display

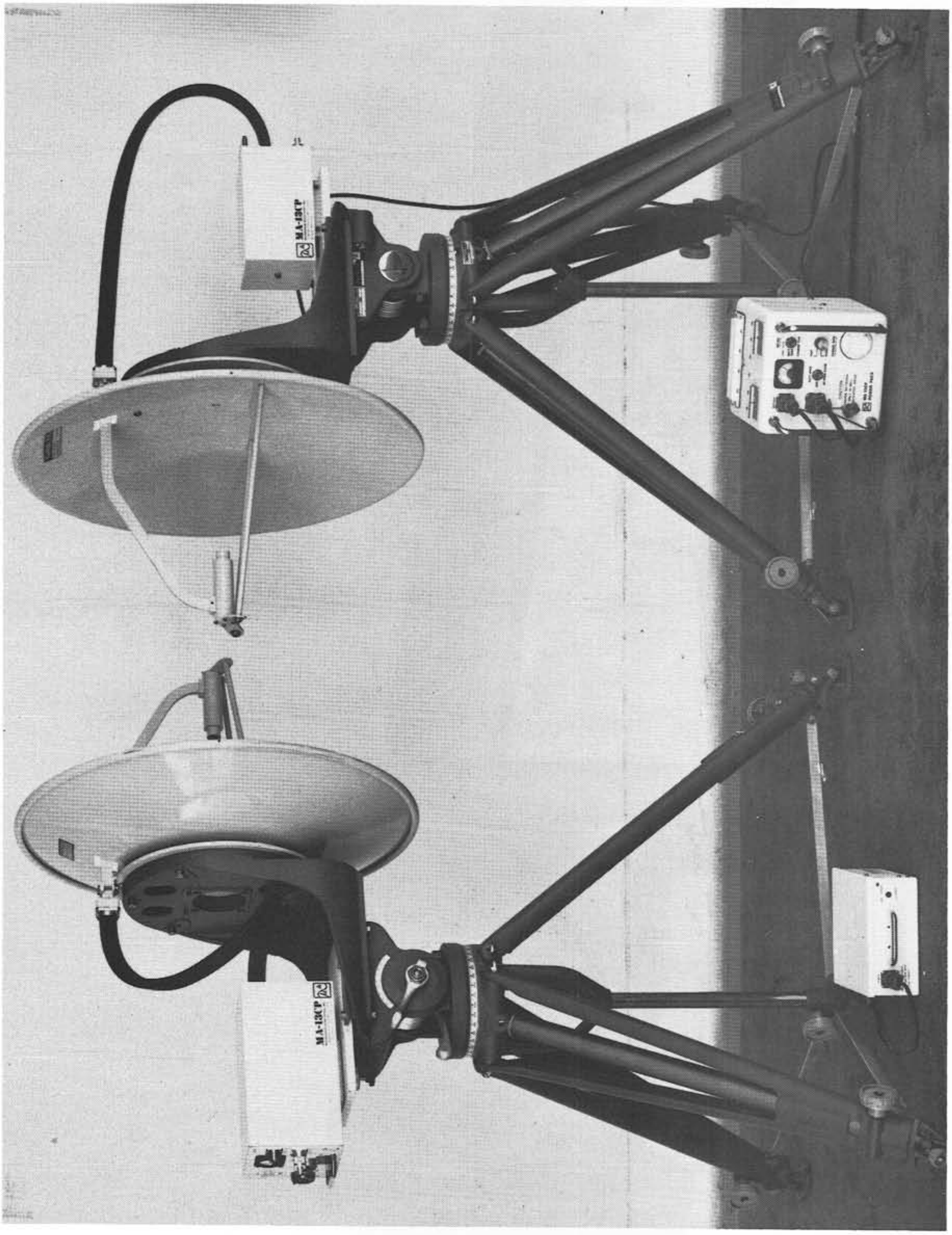


Plate 7. Microwave link - Microwave Associates Type MA-13CP

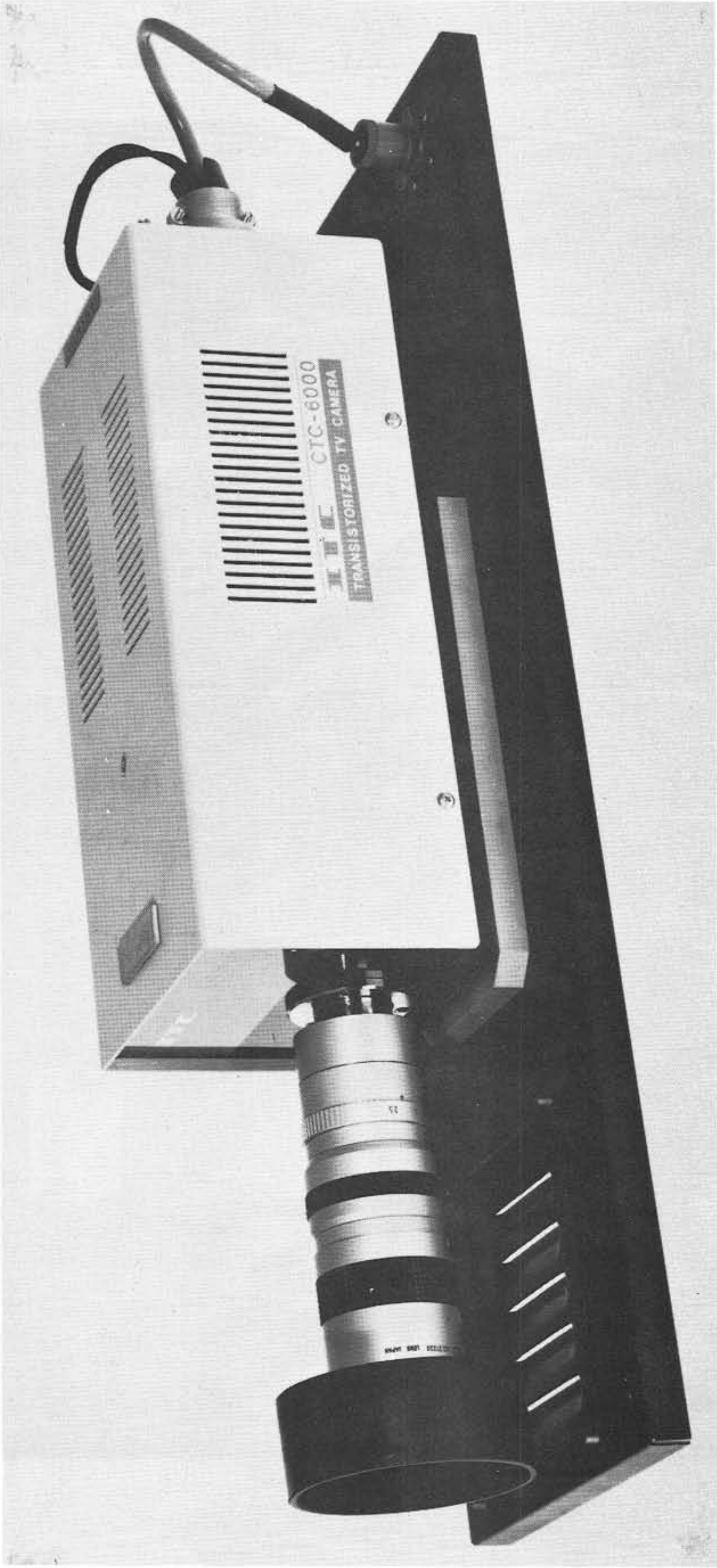


Plate 8. TV camera with zoom lens

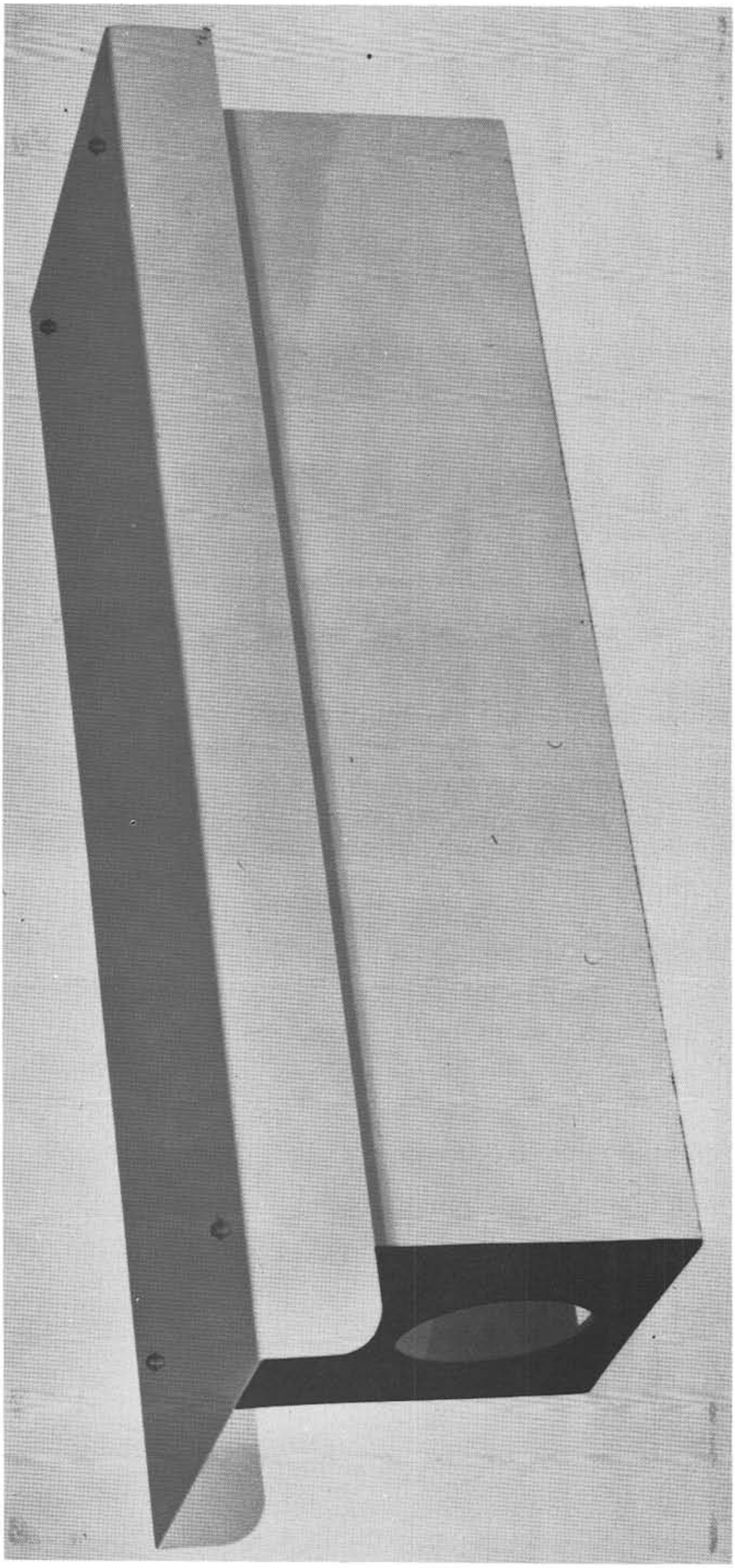


Plate 9. TV camera dust cover and sunshade

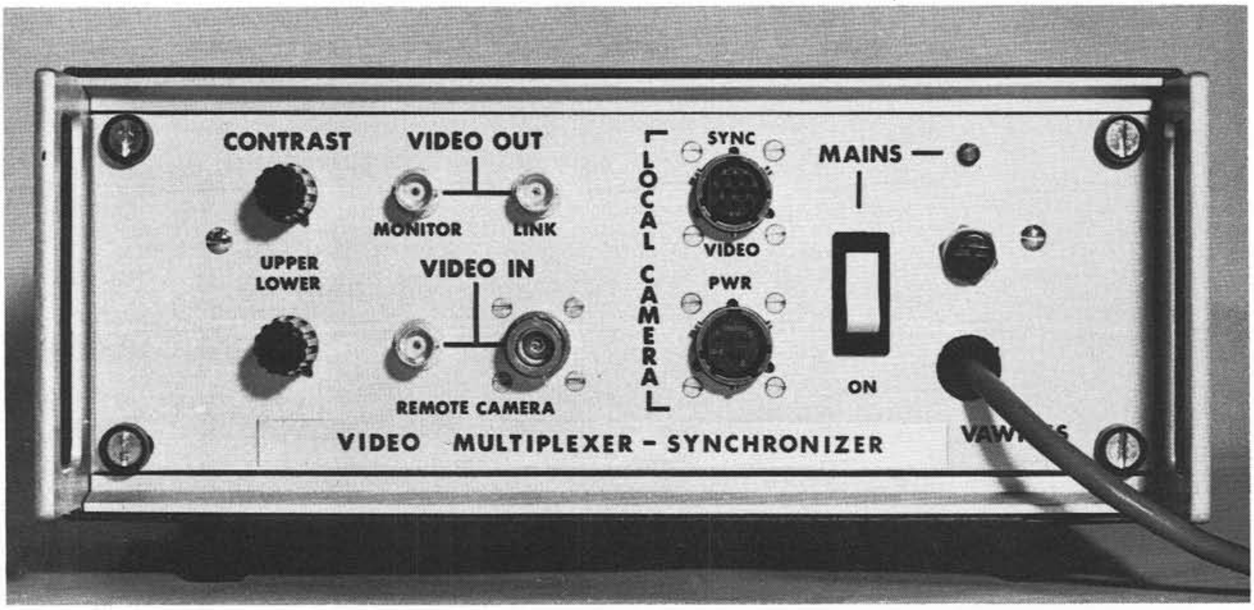


Plate 10. Video multiplexer - synchronizer

TRIALS INSTALLATION

LEARMONTH AIR WEAPONS RANGE

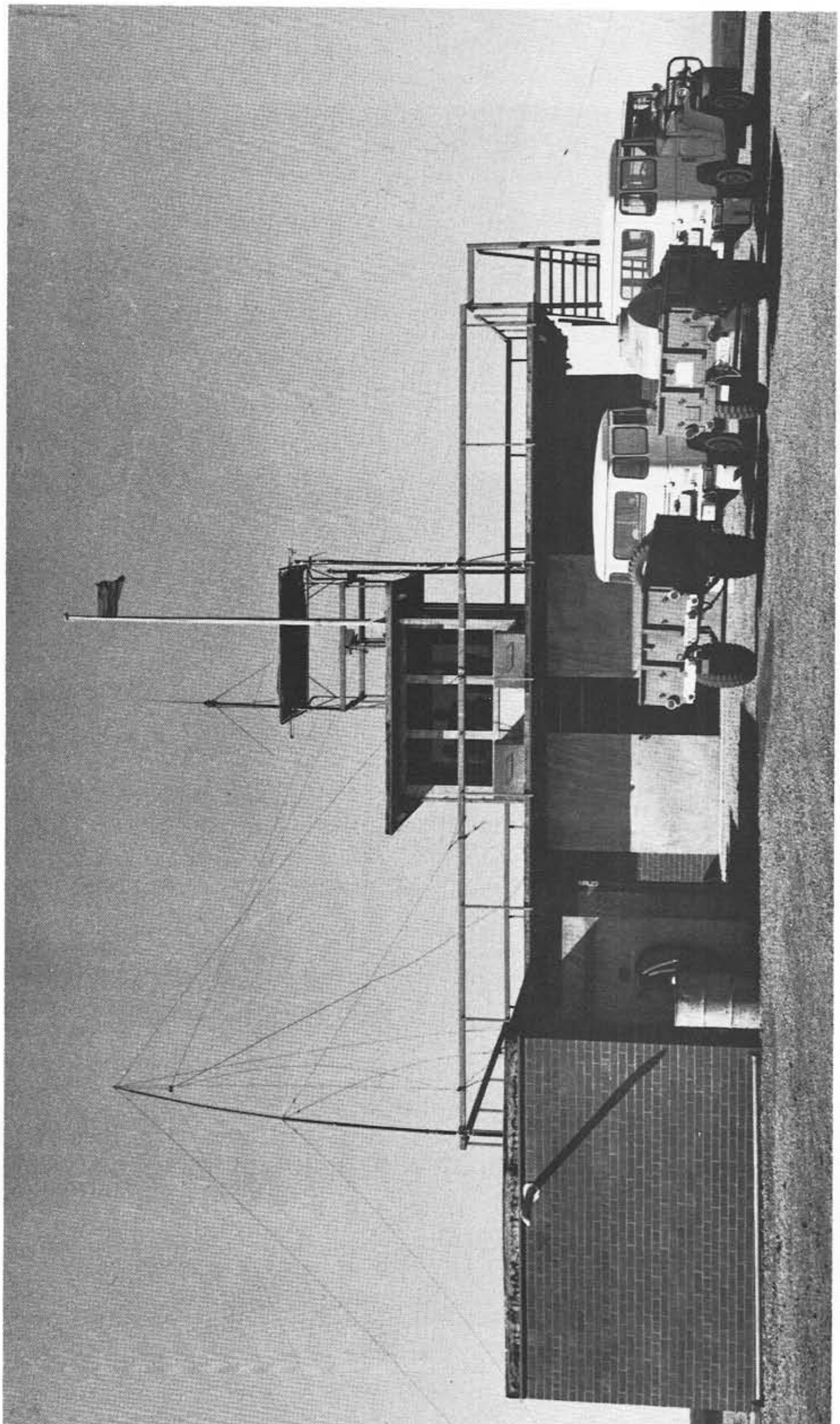


Plate 11. Main tower (Q1) and living quarters

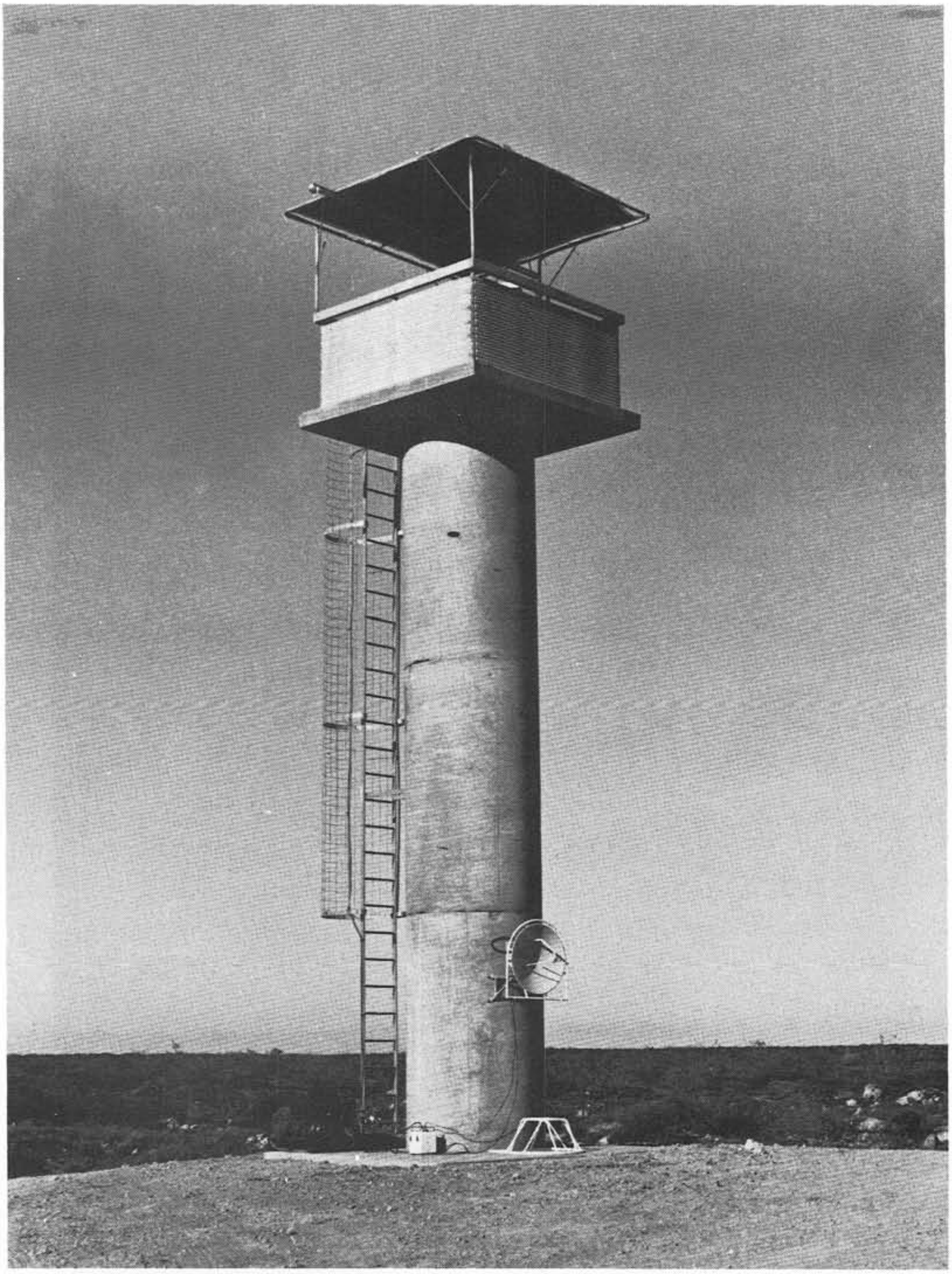


Plate 12. Remote TV camera and microwave transmitter - observation tower (Q3)

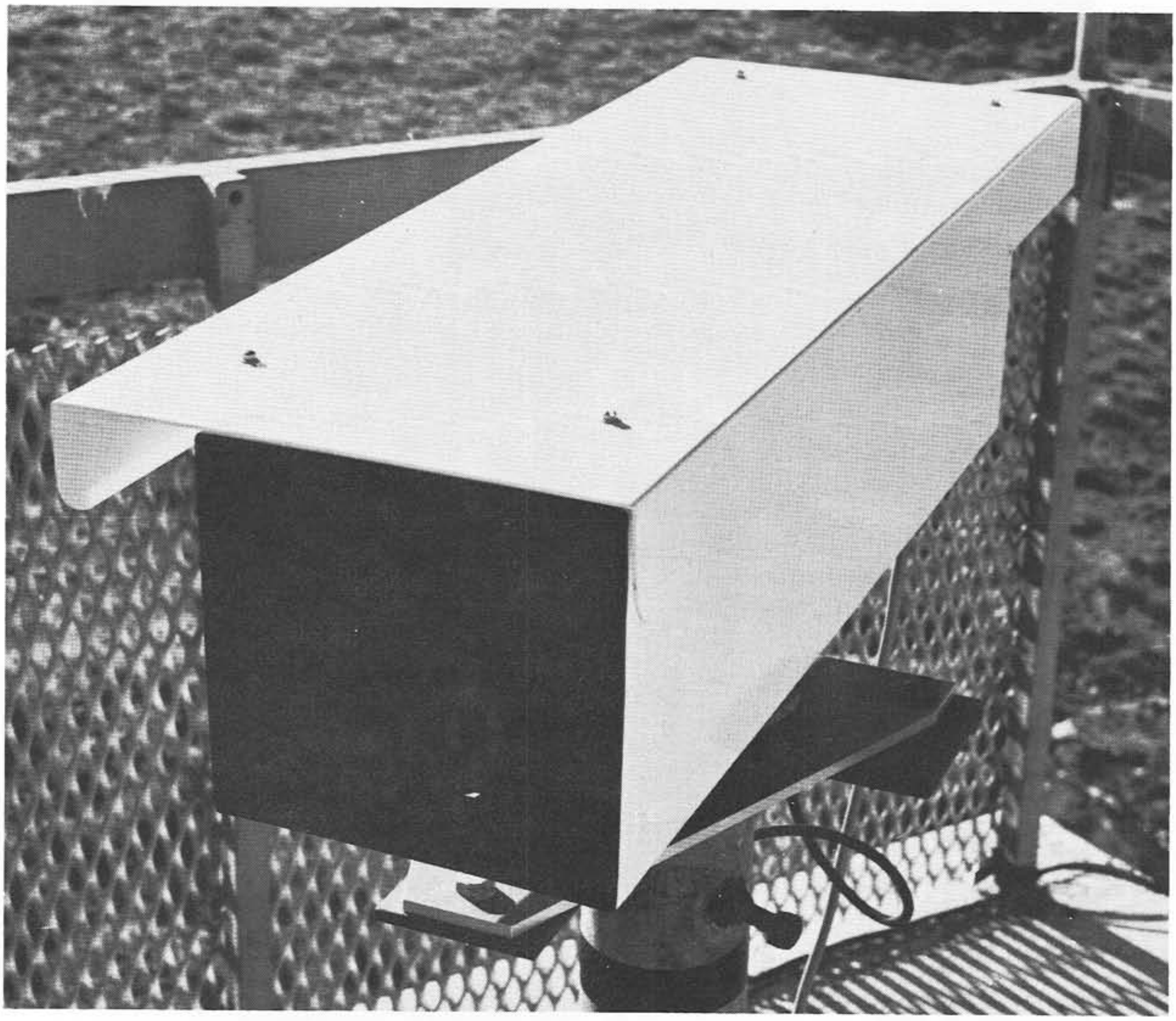


Plate 13. Remote TV camera - observation tower (Q3)

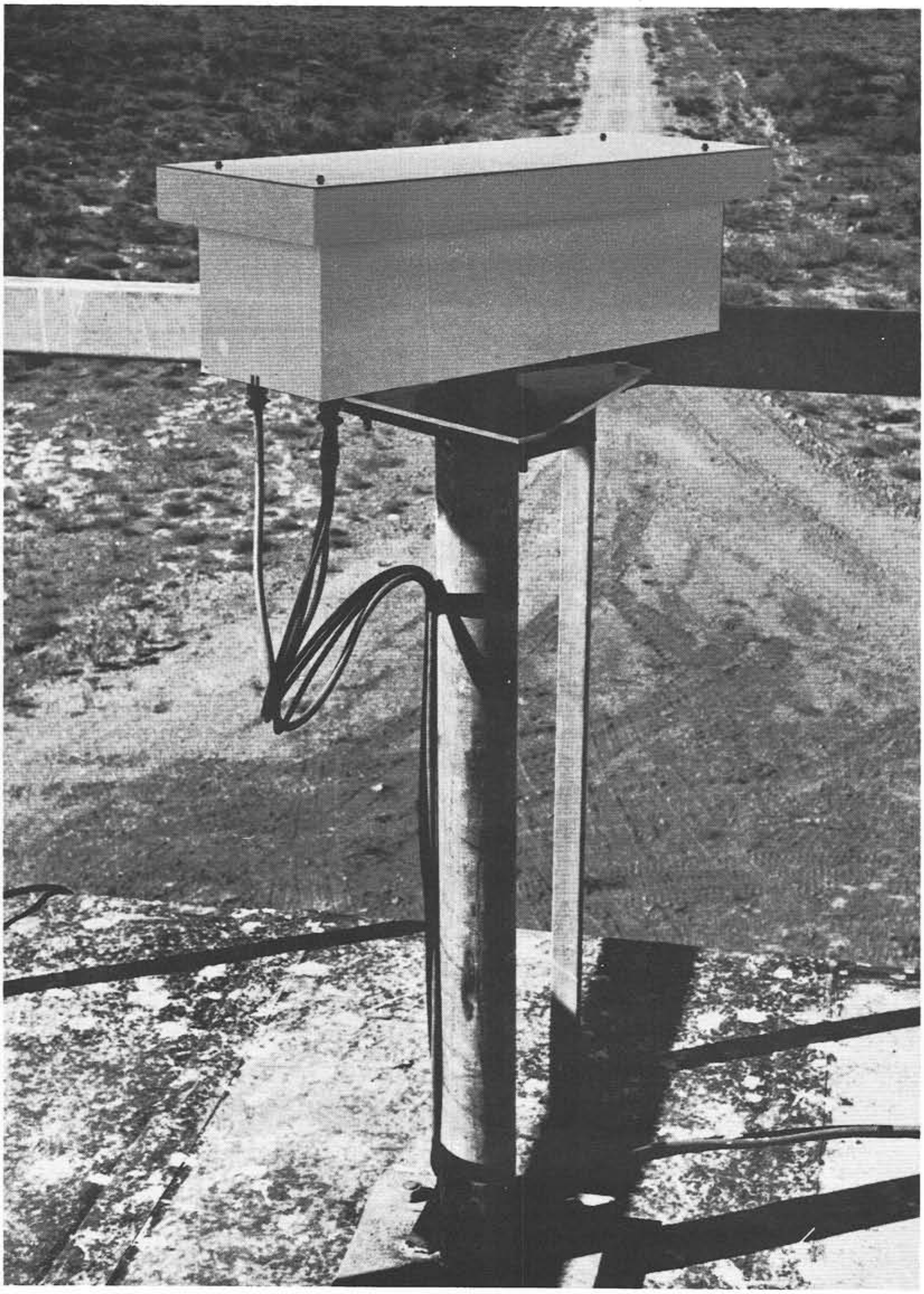


Plate 14. Local TV camera - main tower (Q1)

Plate 15. Microwave receiver - main tower (Q1)

TRIALS INSTALLATION

LAKE HART (WOOMERA) AIR WEAPONS RANGE

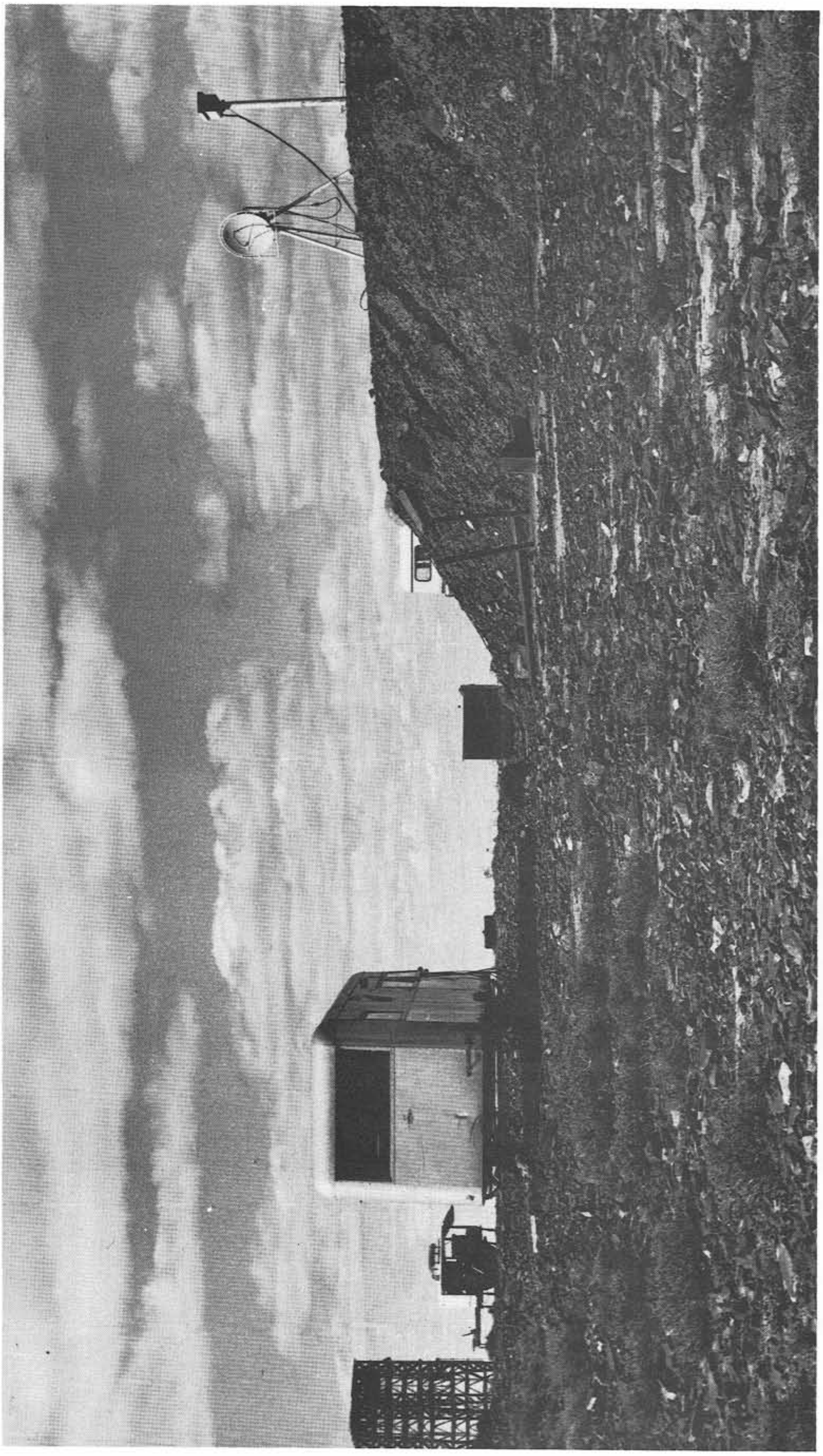


Plate 16. Master quadrant

Plate 17. Local TV camera and microwave receiver - master quadrant

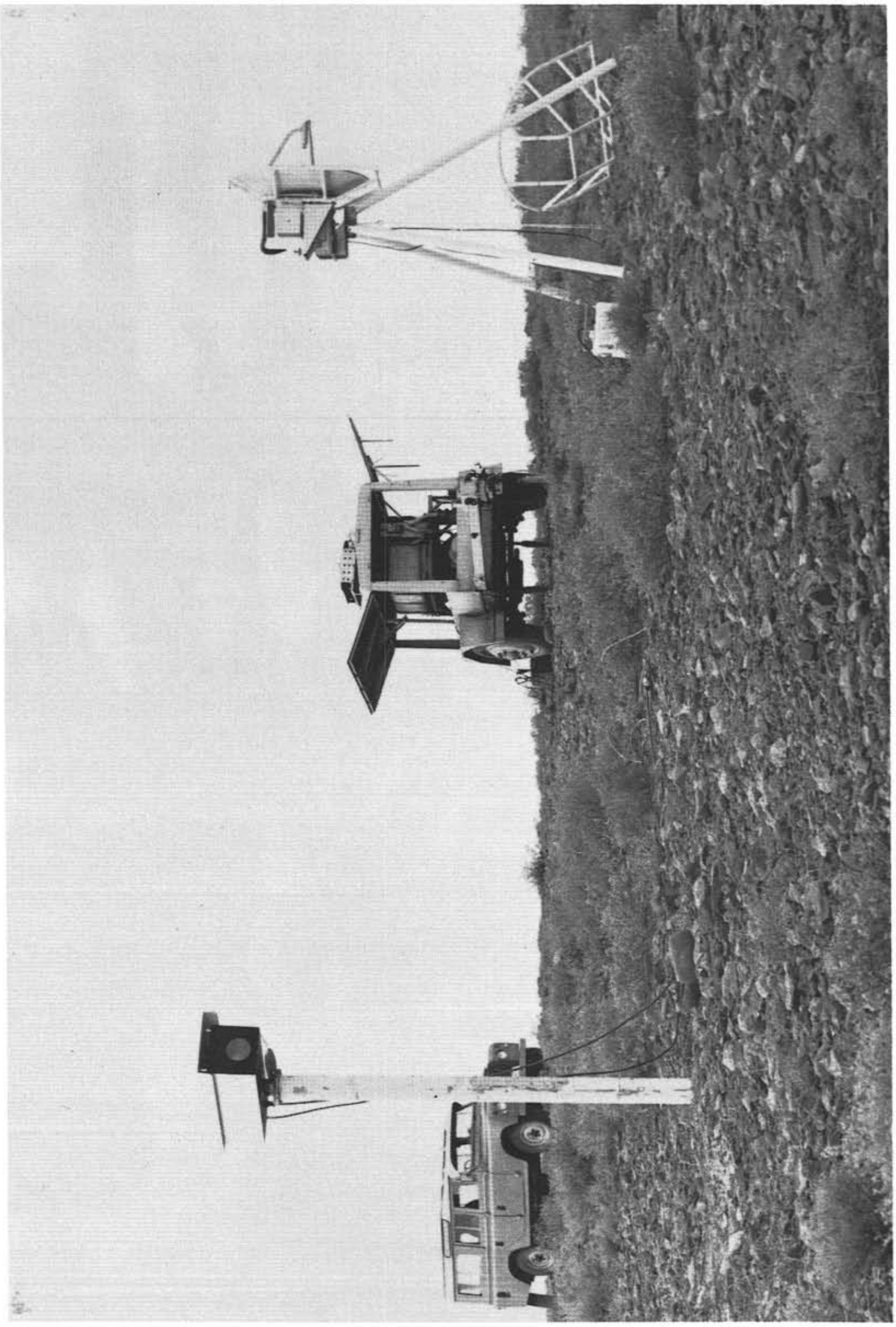


Plate 18. Remote TV camera and microwave transmitter - remote quadrant

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b. Non-Thesaurus Terms	TV bombscoring Bombing triangle		

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17 SUMMARY OR ABSTRACT:
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The Defence Research Centre Salisbury has developed, in close collaboration with the RAAF, a Television Bombscoring System for measuring bombing accuracy on air weapons ranges. A detailed description of the system is given together with accuracy as determined from evaluation on a simulated bombing range.

Security classification of this page: UNCLASSIFIED